DETAILED PROJECT REPORT
VOLUME II - MAIN REPORT
(PART C)

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

KERALA RAIL DEVELOPMENT CORPORATION LTD

DETAILED PROJECT REPORT
VOLUME II - MAIN REPORT
(PART C)

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

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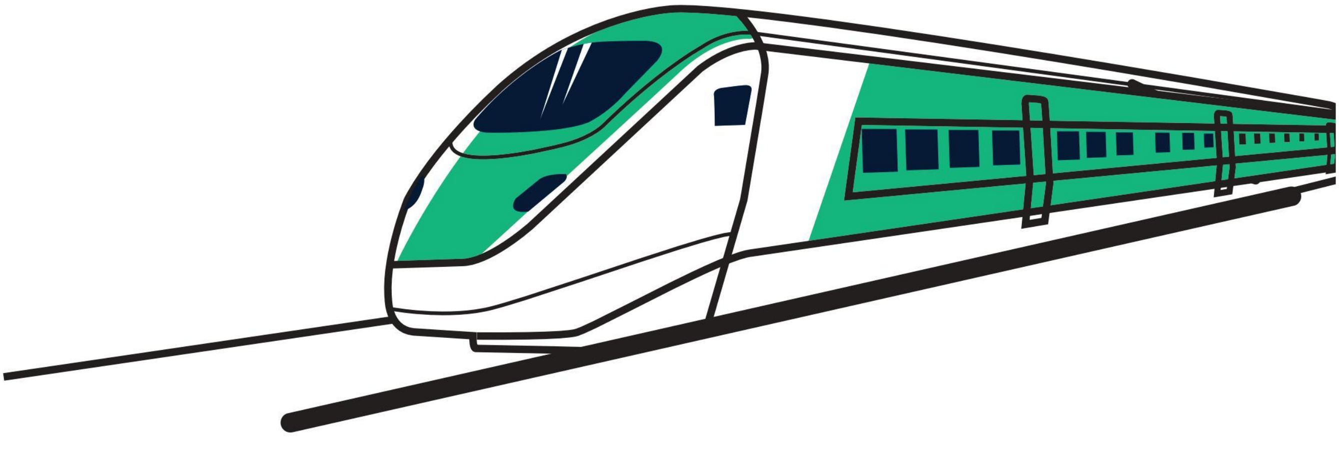

K-rail

SYSTRA

DETAILED PROJECT REPORT – (VOLUME II: PART C)

DETAILED PROJECT REPORT FOR SILVERLINE (SEMI HIGH SPEED RAIL) FROM THIRUVANANTHAPURAM TO KASARAGOD

IDENTIFICATION TABLE

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LIST OF ABBREVIATIONS

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
AD	Acceleration Distance
ASCI	Advanced Speech Call Items
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BCC	Backup Control Centre
BD	Braking Distance
BER	Bit Error Rate
BTM	Balise Transmission Module
BTN	Backbone Transmission Network
CBI	Computer base interlocking
CBTC	Communication Based Train Control
CCTV	Closed Circuit Television
CDRS	Centralised Digital Recording System
CMCC	Central Maintenance Control Centre
CTC	Centralized Traffic Control
CTCS	Chinese Train Control System
DCR	Depot Control Room
DMI	Driver Machine Interface
DMI	Driver Machine Interface
DR	Driver Response
DTO	Driverless Train Operation
DWS	Disaster Warning System
eGPP	3rd Generation Partnership Project
EI	Electronic Interlocking
EIRENE	European Integrated Radio Enhanced Network
EN	European Standard
ENC	Evolved Node Controller
eNodeB	Evolved Node B
EOA	End of Authority
EoS	Ethernet Over SDH
EPC	Enhanced Packet Core
ERA	European Railway Agency
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EVC	European Vital Computer
FDD	Frequency Division Duplex
FRMCS	Future Railway Mobile Communication System

FS	Full Supervision
F-SCADA	Facility -Supervisory Control and Data Acquisition
GbEN	Gigabit Ethernet Network
GoA	Grade of Automation
GSM-R	Global System for Mobile Communication - Railway
HSDPA	High Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HSR	High Speed Rail
HSRL	High Speed Rail Line
HSS	Home Subscriber Server
IEC	International Electromechanical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMA	Issue Movement Authority
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
IP PBX	Internet Protocol Private Branch-Exchange
IR	Indian Railway
IRS	Indian Railway Standards
IS	Isolation
ISO	International organization for Specification
IXL	Interlocking
JRU	Juridical Recording Unit
K-RAIL	Kerala- Rail
KRDCL	Kerala Rail Development Corporation Ltd
KRNA	Korea Rail Network Authority
LAN	Local Area Network
LED	Light-Emitting Diodes
LEU	Lineside Encoder Unit
LMDS	Local Maintenance Diagnoses System
LTE	Long Term Evolution
LTE-R	Long Term Evolution- Railway
MA	Movement Authority
MCPTT	Mission-Critical Push-to-Talk
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
MORANE	Mobile Radio for Railway Networks in Europe
MS-SPR	Multiplex Section Shared Protection Ring
MWT	Maintenance Working Time
NMS	Network Management System
NTG	Network Transmission Gateway
OBUs	Onboard Units
OCC	Operation Control Centre
OEM	Original equipment manufacturer
OFC	Optical Fibre Cable
OFDM	Orthogonal Frequency Division Multiple Access

OS	On Sight
PAS	Passenger address System
PCRF	Policy Charging Rules Function
PGW	Packet Data Network Gateway
PIDS	Passenger Information Display System
PIS	Passenger Information System
PMR	Professional Mobile Radio
PTT	Push to Talk
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAMS	Reliability, Availability, Maintainability and Safety
RBC	Radio Block Centre
RO-RO	Roll ON Roll Out
ROT	Revenue Operation Time
S&T	Signalling & telecommunication
SCADA	Supervisory Control and Data Acquisition
SC-FDMA	Single Carrier Frequency Division Multiple Access
SCR	Station Control Room
SDH	Synchronous Digital Hierarchy
SGW	Serving Gateway
SH	Shunting
SHS	Semi High-Speed
SHSL	Semi High-Speed Line
SHSR	Semi High-Speed Rail
SIL	Safety Integrity Level
SISO	Single Input Single Output
SR	Staff Responsible
STO	Semi-automatic Train Operation
SvL	Supervised Location
TCMS	Train control management System
TD	Train Détection
TDD	Time Division Duplex
TDS	Time Distribution System
TETRA	Terrestrial Trunked Radio
TGV	Train à Grande Vitesse
TI	Train Interface
TLS	Train Location Section
TRS	Trunked Radio System
TS	Train System
TSP	Track Safety Protection
TTA	Telecommunications Technology Association
UE	User Equipment
UIC	International Union of Railways
UMTS	Universal Mobile Telecommunications System
UPS	Uninterrupted Power Supply

UTO	Unattended Train Operation
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
VHF	Very High Frequency
VoIP	Voice over IP
AFC	Automatic Fare Collection
AG	Automatic Gate
BCC	Backup Control Centre
BR	Barcode
BSNL	Bharat Sanchar Nigam Limited
BTN	Backbone Transmission Network
BYOT	Bring Your Own Ticket
CCS	Central Computer System
CONCERT	Country Wide Network for Computerised Enhanced Reservation and Ticketing
CRIS	Central for Railway Information Systems
CTC	Centralized Traffic Control
DOT	Department of Telecommunication
EMV	Europay, Mastercard, and Visa
EN	European Standard
IC	Integrated Circuit
ICS	Industrial Control Systems
IEC	International Electromechanical Commission
IEEE	Institute of Electrical and Electronics Engineers
IR	Indian Railway
IRCTC	Indian Railway Catering and Tourism Corporation
IRS	Indian Railway Standards
ISO	International organization for Specification
KRDCL	Kerala Rail Development Corporation Ltd
LAN	Local Area Network
LCD	Liquid Crystal Display
MTC	Mobile Ticket Counter
NFC	Near-Field Communication
NFPA	National Fire Protection Association
NMS	Network Management System
OCC	Operation Control Centre
OEM	Original equipment manufacturer
OFC	Optical fibre Cable
PII	Personally Identifiable Information
PNR	Passenger Name Record
PPU	Portable Processing Unit
PRS	Passenger Reservation System
QR	Quick Response Code
RAMS	Reliability, Availability, Maintainability and Safety
SC	Security Code
SCS	Station Computer System
SHS	Semi High Speed

SHSL	Semi High Speed Line
SHSR	Semi High-Speed Rail
TOM	Ticket Office Machine
TVM	Ticket Vending Machine
UIC	International Union of Railways
UPS	Uninterrupted Power Supply
AAQ	Ambient Air Quality
AAQM	Ambient Air Quality Monitoring
AIDS	Acquired immune deficiency syndrome
ANQ	Ambient Noise Quality
BIS	Bureau of Indian Standards
BTN	Big Ten Network
BMTPC	Building Materials & Technology Promotion Council
C&D	Construction & Demolition
CGWA	Central Ground Water Authority
CPCB	Central Pollution Control Board
CQWB	Central Ground Water Board
CHCs	Community Health Centres
DG	Diesel Generator
ESIA	Environmental & Social Impact Assessment
EIA	Environmental Impact Assessment
EC	Environmental Clearance
EMC	Electro Magnetic Compatibility
EMP	Environment Management Plan
EMoP	Environmental Monitoring Programme
EMU	Electric Multiple Unit
ETCS	The European Train Control System
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHG	Green House Gas
GoI	Government of India
GoK	Government of Kerala
GW	Ground Water
GWD	Ground Water Department
HIV	Human Immunodeficiency Virus
HSD	High Speed Diesel
IDC	Interest During Construction
IGBT	Insulated Gate Bipolar Transistor
IHME	The Institute for Health Metrics and Evaluation
IS	Indian Standards
JICA	Japan International Cooperation Agency
KSPCB	Kerala State Pollution Control Board
LSG	Local Self Government
LSGD	Local Self Government Department
LTE	Long-Term Evolution
MoR	Ministry of Railways

MoEFCC	Ministry of Environment, Forest and Climate Change
MSMEs	Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
MWL	Maximum Water Level
NAAQS	National Ambient Air Quality Standards
NAAQMS	National Ambient Air Quality Monitoring Series
NH	National Highways
NOC	No Objection Certificate
PHCs	Primary Health Centres
POL	Petroleum Oil and Lubricants
PHPDT	Peak Hour Per Directional Trip
PAP	Project Affected Persons
R&R	Rehabilitation and Resettlement
RoW	Right of Way
SR	Sensitive Receptor
STP	Sewage Treatment Plant
SPCB	State Pollution Control Board
SSIs	Small Scale Industries
SW	Surface Water
UNESCO	The United Nations Educational, Scientific and Cultural Organization
USD	United States Doller
VOC	Vehicle Operating Cost
VVVF	Variable Voltage, Variable Frequency
WGEEP	The Western Ghats Ecology Expert Panel
WHO	World Health Organization
WLS	Wildlife Sanctuary

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 9
ROLLING STOCK & DEPOT

9 ROLLING STOCK & DEPOT

9.1 ROLLING STOCK

9.1.1 Introduction

This Section of the DPR details the performance parameters and the engineering details of the Rolling Stock proposed for the SilverLine corridor from Thiruvananthapuram to Kasaragod.

This document identifies the characteristics of the SilverLine Rolling Stock which will be developed during the execution design stage in line with the development of technical, performance, environmental, maintenance and RAMS requirements.

We have examined the different types of Rolling Stock that can be used on the SilverLine Corridor, their advantages, disadvantages and suitability for the type of service needed and have determined the most suitable stock. In deciding the type of Rolling Stock, consideration given to the operational requirements, interface with infrastructure, whole life cost, as well as the client’s aspirations and the compatibility of the Rolling Stock with that of other Semi High Speed Rail and High Speed Rail corridors.

The proposed Rolling Stock is of EMU type with distributed traction power with design speed of 220 kmph and operating speed of 200 kmph. The car body material is proposed as Aluminium because of the inheriting low weight characteristics.

9.1.2 Context

SilverLine Corridor proposed between Thiruvananthapuram and Kasaragod is about 529.450 KM in length. The corridor contains 11 Stations for passenger boarding and deboarding.

The capacity and the number of the Rolling Stock is based on the passenger trips and the dwell time at the stations. The run time between Thiruvananthapuram and Kasaragod is estimated as four hours approximately. The information related to operation is covered in the respective chapter detailing the capacity and the number of trains required on identified horizon year.

The configuration and performance of the Rolling Stock is based on many factors. Some of the key factors are listed below.

- PHPDT- Peak Hour Peak Direction Traffic
- Headway proposed by Signalling System
- Dwell Time on each station
- Turn Back time on terminal stations

These factors will in turn decide the factors such as axle load, coach main dimensions, acceleration and deceleration etc. The details of the Rolling Stock performance such as axle load, speed, acceleration etc are covered in subsequent chapters and the details of the Rolling Stock component details such as Car body, Bogie etc are covered in the following chapters.

9.1.3 Recommendation as per the Feasibility Report

We recommended the Rolling Stock brief details on the feasibility report submitted to K-Rail. The recommendation is listed in Table 9-1 for the ready reference.

Table 9-1:Feasibility Recommendation

Train Set Composition and Configuration	9 Car Train Sets Extendable to 12/15 Car Train Sets in future	EMU type Non-articulated
Maximum operational speed	200 kmph.	
Acceleration (Approx.)	0.6 to 0.7 m/sec/sec	Initial acceleration
Average deceleration	0.7 to 0.8 m/sec/sec	Emergency braking rate of 1.2 to 1.3 m/sec/sec
Maximum axle load	16 Tonne or less	The lighter is preferable
Car body width	3,400 mm (maxi)	
Passenger capacity (Approx.)	675 persons: 9-car train set	
Seating arrangement	5-seat (2+3) arrangement 4-seat (2+2) arrangement	Standard class Executive class
Car body structure	Aluminium structure	
Type of bogie	Bolster-less type	Air spring suspension system
Track gauge	Standard gauge- 1,435 mm	
Supply power system	AC 25 kV 50 Hz	
Approximate Electric load of 9-car train	5.0 MVA (Approximately)	

Train Set Composition and Configuration	9 Car Train Sets Extendable to 12/15 Car Train Sets in future	EMU type Non-articulated
Traction circuit and configuration	VVVF inverter control Using IGBT and asynchronous traction motor	
Braking system	Regenerative brake Electric/Pneumatic brake blending	Normal and Emergency
Emergency braking distance	< 1300 m	

This chapter detailed below will elaborate the parameters with substantial data. The recommendation proposed above is provided as part of the feasibility study with limited information. However, this chapter covers details based on detailed traffic studies conducted by K-Rail, simulation and references available across the globe.

9.1.4 Codes and Standards

The SilverLine Rolling Stock is proposed in accordance with the latest standards revision of International standards such as UIC, EN, IEC etc.

However, the proposed Rolling Stock will meet the requirement of the Indian Statutory requirements.

9.1.5 Interfaces with Other Systems

9.1.5.1 Generalities

The Rolling Stock will be interfacing with other subsystems proposed in the corridor. The important subsystems to which Rolling Stock interfaces are listed below.

- Track,
- Overhead Catenary System,
- Signalling & Train Control and Communication system
- Civil Work,
- Track Work
- Depot Equipment,
- Tunnel Ventilation System

9.1.5.2 Track Characteristics

Proposed SilverLine Corridor track gauge is the standard gauge - 1435mm.

The maximum axle load of the track is 22.5 tonne considering the RORO service (at 120 kmph).

Maximum longitudinal gradient on SilverLine Corridor – 16%

Minimum curves radius in depot – 200m

Minimum curves radius in main lines- 1850m

Minimum Vertical radius- 17500m (both dip and hill)

Maximum cant – 160mm

Maximum Cant Deficiency- 100mm

9.1.5.3 Signalling & Train Control and Communication System

ERTMS/ETCS Level-2 with LTE based Signalling & Train Control and Communication system is proposed for the SilverLine corridor. The Rolling Stock shall be compliant to the Signalling & Train control system during the interfacing of the subsystems. The antennas and detectors required for the Signalling & Train control system requirement are to be mounted on car body and bogie as per requirement.

9.1.5.4 Overhead Catenary System

25 KV, 50 Hz Overhead Catenary copper conductor is used to provide the power to the Rolling Stock. Rolling Stock will collect the power from the OHE using the pantograph mounted on the Roof of the Rolling Stock Car.

9.1.6 Selection of Rolling Stock Technology

9.1.6.1 Car body Material

Among the semi high-speed railways in the world, the car bodies are made of steel or an aluminium alloy. Aluminium alloy is lighter than steel and is highly resistant against corrosion. So aluminium alloy is mainly used for semi high speed/HSR which strongly requires light weight body structure.

Table 9-2: Global Reference for Car body

Country	Japan		France		German	Italy		
Class	Series E 5	Series E 4	TGV-R	TGV-D	ICE1	ICE3	ETR-500	AGV-Itaro
Car body Material	Al.alloy	Al.alloy	steel	Al.alloy	Al.alloy	Al.alloy	Al.alloy	Al.alloy

Country	Spain		China		Taiwan	South Korea
Class	S100	S103	CRH2C	CRH- 3	700T	KTX – 1
Car body Material	Steel	Al.alloy	Al.alloy	Al.alloy	Al.alloy	Steel

The entire length of Thiruvananthapuram to Kasaragod corridor runs parallel to the coastal line and has a highly corrosion environment. Hence Aluminium car body is recommended.

9.1.6.2 Distributed or Concentrated Power

Now a days, the trains at the maximum speed of over 200 km/h normally use fixed train sets, while combining two sets into one as necessity arises to cope with fluctuation of transport demands. Regarding power distribution of these fixed train sets, there are two types. One is concentrated power system (Loco system) and the other is distributed power system (EMU) adopted by Japan, China and ICE-3 in Germany for its latest train compositions.

In conventional railway, Loco system was a mainstream of long-distance train. Regarding semi- high speed and high-speed trains, both Loco and EMU had advantages and disadvantages in some viewpoints, and they have been used respectively in accordance with their role.

Recently, as the maximum operation speed is increasing, even in the conventional high-speed trains, adoption of EMU system become dominant, because of the advantages of EMU have exceeded. The following Table 9-3 are advantages of EMU system.

Table 9-3: Advantages of EMU

Characteristic	EMU	Loco	Remarks
Traction Performance	EMU has greater acceleration/ deceleration performance	Loco has lower performance in comparison	EMU realize acceleration over 0.8 m/sec/sec, while Loco under 0.4 m/sec/sec, resulting shorter traveling time
Acceleration	Quick acceleration & deceleration. Reduction in travel time.	Sluggish acceleration and deceleration.	

Characteristic	EMU	Loco	Remarks
Passenger Capacity	Higher passenger capacity	Lower passenger capacity	EMU can accommodate 20% of higher passenger approximately as there is no power cars at ends of the train
Axle Load	EMU has lower axle load compared to Loco	Loco has higher axle load for the same capacity	As all the traction equipment are to be concentrated on Loco, the axle load increases
Adhesion	Higher adhesive force	Lower adhesive force	EMU will have good acceleration and speed in higher gradients. EMU will have higher adhesive force in wet rail condition also.
Travelling Time	Lower Travelling time	Higher Travelling time	EMU has higher acceleration and deceleration rates. Hence the travel time is less compared to Loco
Energy Efficiency	Higher regeneration	Lower Regeneration	EMU has enough regenerative brake power due to multiple power system equipped
Reliability	Very high reliability	Low reliability	If one of the motor cars fails also, EMU performs in normal condition. However, if one Loco fails, it will affect the performance of the train

Characteristic	EMU	Loco	Remarks
Competition	Most of the manufactures has EMU trainset	For high speed application, limited option is available	All the manufactures have EMU type train currently available for 200 kmph. Some manufactures such as Talgo, Rotem & Alstom still produces Loco for 200 kmph. Chinese preferred EMU trainset for their high speed trains from the beginning.
Maintenance	EMU has higher maintenance	Loco has lower maintenance	Even though lower maintenance for Loco alone, in the train level the maintenance effort for both EMU and Loco almost same.
Aesthetics	EMU trains appear aesthetically good compared to Loco	Compared to EMU, aesthetical appearance is limited	
Platform Utilisation	Better utilisation of platform space as locomotive is not required.	Inferior utilisation of platform lengths as locomotive takes up some length.	
Coupler Forces	Uniform weight distribution. Lower coupler forces.	Concentrated weight in locomotive. Higher coupler forces	

Globally most of the high-speed rail also adopts the EMU type of train sets for their corridor.

- Germany changed adopting design from Loco type (ICE-1, 2) to EMU since 2000 at the inauguration of ICE-3.
- China has decided design policy that EMU system should be adopted for HSR at the beginning of HSR development in 2004.
- Alstom which is the supplier of TGV: one of the most famous Loco systems for HSR: has already developed AGV which is next-generation HS train under the distributed traction system.

Considering above benefits of EMU trainsets over Loco hauled trains, EMU type train sets are proposed for SilverLine corridor. Moreover, SilverLine corridor has gradient of 1.6%, EMU trains will perform in its full capacity even in the wet rail condition.

9.1.6.3 Passenger Capacity

As per the traffic requirement, we need to carry nearly 1000-1100 passengers with 375 m train length, EMU train preferred over Loco hauled trainsets. **Table 9-4** gives a comparison of the EMU and Loco hauled trains passenger capacity.

Table 9-4: Comparison of EMU and Loco

Series	TGV-R(France)	ICE-3(Germany)	E2 (Japan)
Type	Loco	EMU	EMU
Train-length	200 m	200 m	200 m
Body-Width	2904 mm	2950 mm	3380 mm
Passenger capacity	375 seats	444 seats	630 seats

Hence a configuration EMU train with 15 Car having total length of 375 m is proposed for the SilverLine corridor.

9.1.6.4 Car body Width

The loading gauge widely used in Europe is the “UIC loading gauge, type C,” to limit car body width to 3,150 mm or less. Therefore, standard cars have a car body width of 3,000 mm or less, with ordinary train sets designed to a structure having 4-seats arrangement (two 2-seats arrangement). In contrast, Japan, China and Taiwan adopted a loading gauge to make the car body width 3,400 mm or less to make 5-seat arrangement (2-seats/3-seats arrangement) possible. **Table 9-5** shows the loading gauge and car body widths adopted in different countries.

Table 9-5: Global Reference of Loading Gauge

Country	Japan		France		German		Italy	
Class	Series E 5	Series E 4	TGV-R	TGV-D	ICE1	ICE3	ETR-500	AGV-Itaro
Car body width (mm)	3350	3380	2904	2896	3020	2950	2860	3000

Country	Japan		France		German		Italy	
Seat Arrangement	2+3	3+3 2+3	2+2	2+2	2+2	2+2	2+2	2+2
Country	**Spain**		**China**		**Taiwan**		**South Korea**	
Class	S100	S103	CRH2C	CRH3	700T		KTX - 1	
Car body width (mm)	2904	2950	3380	3260	3380		2904	
Seat Arrangement	2+2	2+2	2+3	2+3	2+3		2+2	

Considering the global scenarios and the future requirements, we recommend a maximum body width of 3.4 m for the SilverLine corridor.

9.1.6.5 Bogie Type

There are mainly two types of Bogie mounting: Articulated and non-articulated type bogie mounting. One of the most outstanding differences is the size of effective space appropriated for passengers, in that the articulated system has more car-end sections in number to reduce the effective space for passengers. Articulated has lower capacity than non-articulated by 20% approximately. Therefore, it is easier to realize mass-transport with the non-articulated bogie system than with the articulated bogie system.

9.1.6.6 Single Deck or Double Deck coaches

The coaches are coming in single deck as well as double deck in both EMU configuration and Loco configuration. Different aspects of single deck and double deck are discussed in Table 9-6.

Table 9-6: Comparison of Double Decker and Single Decker

Characteristics	Single Deck	Double Deck	Remarks
Passenger Capacity	For the same length of the train, lower passenger capacity	For the same length of the train, higher passenger capacity	Alstom single deck-754 Seat Alstom double deck- 1020 Seat Japan N700 single deck-1323 Seats Japan E4 double deck-1634 seats
Competition	Many manufactures are there for	Alstom supplies Loco hauled double decker coaches and Japan	There only two manufacturers for the double decker configuration. Out of the two, one is providing EMU

Characteristics	Single Deck	Double Deck	Remarks
	single deck coach supply	Consortium supplies EMU type double decker coaches	type trainsets while the other provides Loco hauled type trainsets. Hence the competition in double decker coaches is null.
Capital cost	Less cost	More cost	As most of the equipment are to be compacted in the space available in double decker and interior cost is high in double decker with steps and lift facilities. Moreover, less competition lead to higher pricing.
Platform Height	Generally, vehicle floor height varies from 1200-1100 mm	The vehicle floor height varies from 314 mm (Alstom)- 1300 mm (Japan)	The platform height depends on the manufacturer of the Rolling Stock in double decker coaches whereas in single deck the platform height can be fixed in the early design itself.
Vehicle Height	The vehicle height falls below 4000 mm (Bare Car body)	The vehicle height for Alstom is 4303 mm and that of Japan train is 4485 mm (Bare Car body)	The gauge of the double decker will be much broader and higher in height because of the crosswind effects and higher dimension.
Axle Load	Lesser axle load	Higher axle load	
Maintenance	Maintenance is easy	Maintenance is difficult	As the undercar space is no longer available, the equipment is typically installed in lockers located inside the vehicle or in exterior locations such as on the roof.
Passenger boarding/egress	Easy egress of passenger	Egress is difficult	Special staircases and lower head room makes the egress to the train difficult. Moreover, the luggage space is limited in

Characteristics	Single Deck	Double Deck	Remarks
			double decker due to space constraint. It will lead to increase in the dwell time at stations
Ceiling height	For single deck train the ceiling height is 2200 mm	For double deck train the ceiling height is 1900 mm	Double deck trains have less head room

From the above table, considering the infrastructure requirement and availability in the market, double decker coaches are not feasible for the SilverLine corridor. Hence single deck trains are proposed for the SilverLine corridor.

9.1.6.7 Articulated Bogie or Non articulated Formation

From the viewpoints of manufacturing cost and ride comfort, articulated or non-articulated trains are not significantly different from each other, despite that their technologies have developed to satisfy different requirements. Whereas articulated train sets are advantageous for maintenance to the extent that they incorporate fewer bogies in number, they require cumbersome operation for train set composition/decomposition. This means that either system has merits and demerits simultaneously.

One of the most outstanding differences is the size of effective space appropriated for passengers, in that the articulated system has more car-end sections in number to reduce the effective space for passengers. In comparison the articulated and non-articulated trains in which the ratio of effective space of articulated bogie system is taken as 90% of that of non-articulated bogie system. Articulated has lower capacity than non-articulated by 20% approximately. Moreover the articulated bogie system us not suitable for alignment having many curves which are sharper. Therefore, it is easier to realize mass-transport with the non-articulated bogie system than with the articulated bogie system.

9.1.7 Rolling Stock Configuration & Dimension

9.1.7.1 Rolling Stock Type

The proposed SilverLine Rolling Stock will be a transportation system which provides an optimized and flexible response to Kerala’s mobility needs.

For the SilverLine Corridor, EMU type Rolling Stock with distributed power is proposed. The Car shall be manufactured with Aluminium material with state of art interior having seating only. Each car will be provided with two bogies of non-articulated bogie system. The vehicle shall be reversible with a driving cab at each end. The traction motorization is kept preferably as 66% considering the acceleration and deceleration and motor ratings.

Each car of the vehicle is connected by vestibules for the easy passage of the passengers. Passenger Doors are proposed for external entry as well as in between cars. All the cars shall be air conditioned with roof mounted air conditioners.

The Rolling Stock collects power supply from OHE through pantograph. The train is controlled by LTE based ERTMS Level-2 Signalling & Train Control system.

9.1.7.2 Rolling Stock Configuration

Based on the PHPDT arrived by the traffic study, the following number of cars in a train are proposed for the different horizon year in Table 9-7..

Table 9-7: Configuration of Trains

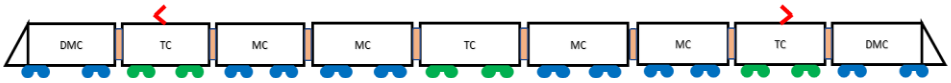
Year	Number of Cars in a Train
2025-2026	Nine Cars
2029-2030	Nine Cars
2041-2042	Nine Cars & Fifteen Cars
2052-2053	Nine Cars & Fifteen Cars

There are motorised cars on which the traction motors are mounted and non-motorised cars which are called as trailer cars. Each car has connected each other by couplers and vestibules.

The following types of preferable configuration are arrived based on the global references and simulation for achieving the acceleration and deceleration, adhesion etc. parameters.

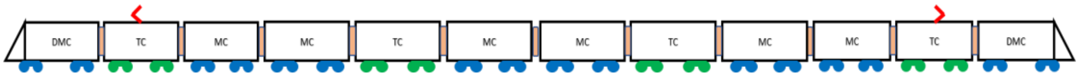
9 Car train Configuration

DMC-TC-MC-MC-TC-MC-MC-TC-DMC



12 Car train Configuration

DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC



15 Car train Configuration

DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC

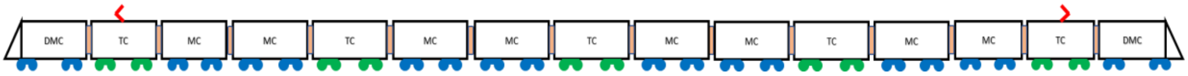


Figure 9-1: RS Configurations

Where,

DMC- Driving Motor Car- Driving cab is provided and propulsion system with traction motors are provided.

TC- Trailer Car- No propulsion system is provided on this car.

MC- Motor Car- Propulsion system with traction motors are provided

The proposed Rolling Stock configuration is summarized in **Table 9-8**. However, it shall be noted that the configuration is proposed and preferred based on the prevailing gradient and acceleration requirement. During project execution, suitable configurations can be selected provided that the configuration meets all the requirements.

Table 9-8: RS Configuration Summary

No of Cars	Layout	Explanation
Nine Cars	DMC-TC-MC-MC-TC-MC-MC-TC-DMC	6 Motorized Cars out of which two are driving motor cars 3 Trailer Cars
Twelve Cars	DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC	8 Motorized Cars out of which two are driving motor cars 4 Trailer Cars
Fifteen Cars	DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC	10 Motorized Cars out of which two are driving motor cars 5 Trailer Cars

9.1.7.3 Train Main Dimensions

There are three type of cars identified as Driving Motor car, Trailer car and Motor Car. This section details the generalized dimensions of the proposed Rolling Stock. The dimension of the train is arrived based on the traffic parameters and the other high-speed train references across the globe.

9.1.7.3.1 Width

The loading gauge means the contour of Rolling Stock (maximum height and width) to guarantee safety of train operation against bridges, tunnels and other structures. Wide body type, Car body width of maximum 3,400 mm, should be selected for providing more comfort keeping passenger capacity with a formation of 5-seats arrangement. It can also realize two 3-seats arrangements. As detailed in the feasibility report, the width of the car body is arrived as maximum of 3.4 meter considering the maximum passenger/floor area and to accommodate 2+3 type of seating. The construction gauge dimensions are arrived considering the maximum car body width of 3.4 meter.

9.1.7.3.2 Length

Car body length of different high speed trains are listed in **Table 9-9** for reference.

Table 9-9: Lengths of Car

Series	Eurostar-UK	ICE-3 (Germany)	Trenitalia-Italy	E2 (Japan)	Renfe-Spain	CRH2A-China
Type	EMU	EMU	EMU	EMU	EMU	EMU
Average Car-length	25 m	25 m	25 m	25 m	25 m	25 m

The maximum length of the car has impact on the construction gauge and radius of curve on the mainline as well as depot. The maximum length of the car is arrived based on the floor layout plan including seating arrangement, toilets etc. The length of the car is proposed as maximum 25 meters over the couplers. The Driving motor car shall accommodate the driving cab also in the prescribed length. The nominal length of different configuration of trains are listed below.

9 Car- Maximum 225 Meters

12 Car- Maximum 300 Meters

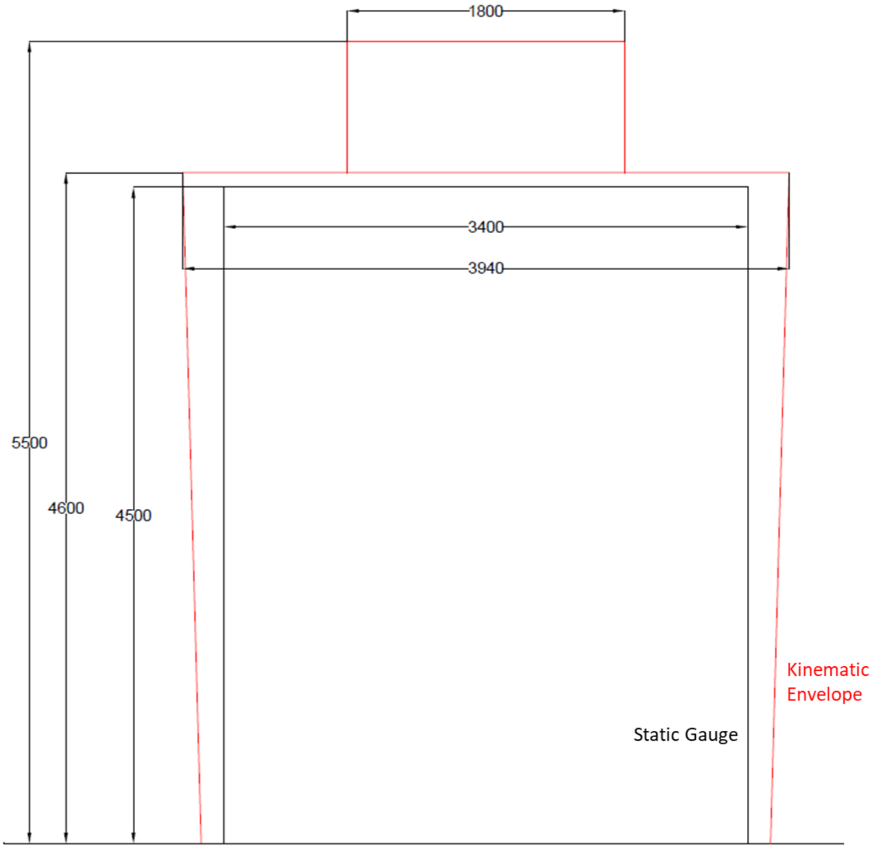
15 Car- Maximum 375 Meters

9.1.7.3.3 Height

The maximum height of the Rolling Stock impacts the height of the tunnel and overhead catenary system. The nominal height of the Rolling Stock is proposed as 4.5 Meters from the rail level considering the roof mounted air conditioners and the pantograph.

9.1.7.3.4 Kinematic Envelope

Considering the Kinematic envelopes used by Japanese high-speed trains and the European high-speed trains (TSI), a kinematic envelope is developed for the proposed corridor. The Kinematic envelope considers the pantograph operation condition. However, the actual Kinematic envelope shall be developed by the OEM of the Rolling Stock.



**All Dimensions are in mm.*

Figure 9-2:Tentative Kinematic Envelope

9.1.7.3.5 Bogie Dimensions

Non- articulated type of Bogies is proposed for the SilverLine Rolling Stock. There are mainly two bogie dimensions which are important in relation to the alignment and construction gauge. One is the bogie center to center distance in the same car and second is the wheelbase in the same bogie. Based on the track alignment parameters such as minimum radius of curve, track twist etc., suitable wheelbase and center to center distance of the bogie shall be arrived during the design stage of the Rolling Stock.

9.1.7.4 Floor Layout plan

Floor layout plan explains the generalized arrangement of the components inside a car. The following types of layout plan is defined in the train configuration.

- **(i) Executive Coach**: In each configuration of the train (9/12/15 Cars), one DMC coach is ear marked for executive coach with 2+2 seating arrangement.
- **(ii) Normal Coach**: In each configuration of the train (9/12/15 Cars), except one coach all other coaches are to be provided with normal seating with 2+3 type seating.

(iii)**Normal Coach with Pantry**: In one of the normal coaches, a specific area for pantry shall be identified. The pantry consists of cold storage, heater and water boiling facilities and no live cooking is envisaged.

(iv)**Normal Coach with facilities for PRM**: In the other DMC Coach, a specific area for persons with reduced mobility (PRM) shall be provided. The coach shall contain facilities for PRM such as wheelchair area. The specific coach shall have toilets designed for persons with reduced mobility. The PRM coach shall be located based on detailed design of the station layout and operation plans.

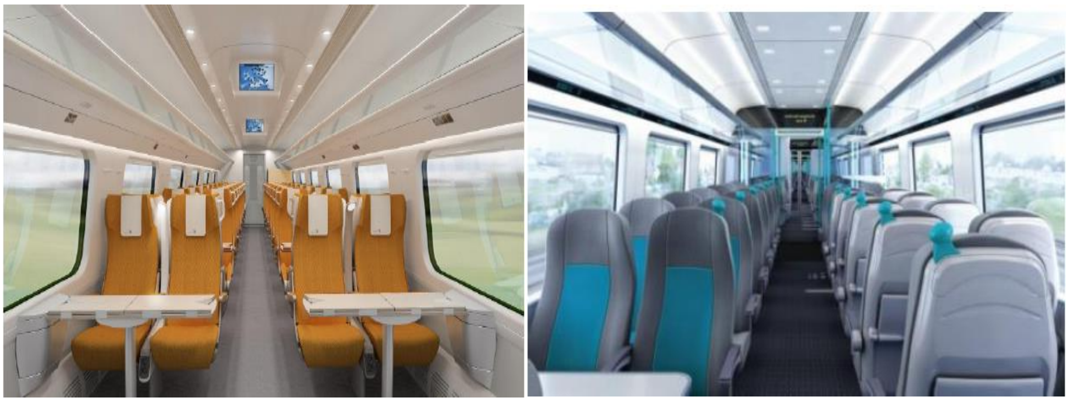


Figure 9-3:Typical Executive Coach Layout

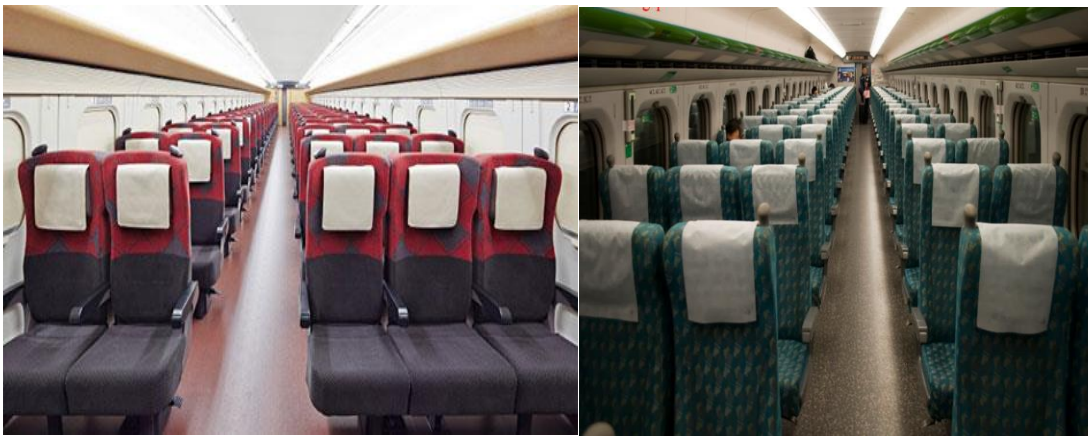


Figure 9-4:Typical Normal Coach Layout

In addition to the above identification, the following points also shall be considered for the proposed Rolling Stock

- Luggage Racks- Luggage racks shall be provided on one end of the car and along the length of the car on the upper sideline.
- Driving Cab shall be provided on each end car accommodating all the equipment necessary for the driver operation.
- There shall be two doors on each side of the train for boarding and deboarding from the station. In addition to these two ends of each car shall be provided with

end doors for smooth passenger flow (In Driving car only one end of the car is to be provided with door for passenger movement).

- Toilet facility for normal passengers as well as the persons with reduced mobility. Two toilets per car is proposed.
- Reclining seats should be adopted both for business and standard class accommodations to improve seating comfort.

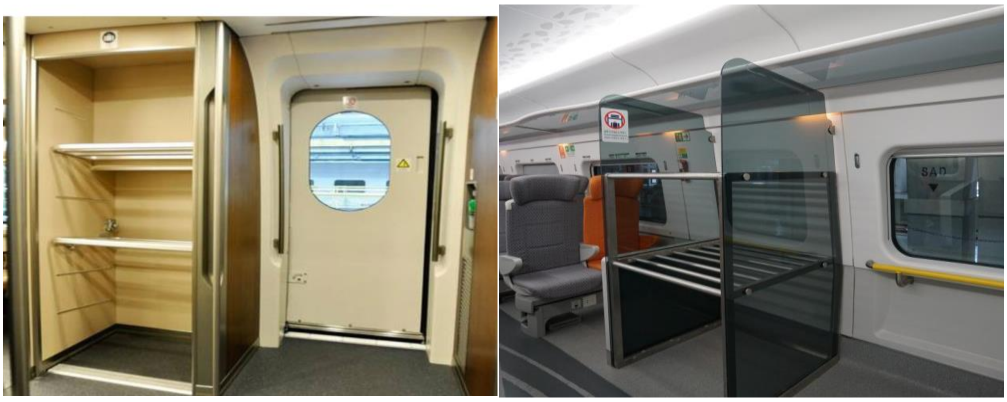


Figure 9-5:Luggage Racks

9.1.7.5 Seating Capacity

Considering the above explained floor layout, the approximate seating capacity for each configuration of trains listed in **Table 9-10**.

Table 9-10:Seating Capacity

Train Configuration	Approximate Seating Capacity
9 Car Train	650 Seats
12 Car Train	890 Seats
15 Car Train	1130 Seats

The above seating capacity is an approximate number arrived on the various references. The actual number of seats shall be detailed during the project execution stage.

9.1.7.6 Summary of Train Main Dimensions

Table 9-11:Summary of Train Main Dimension

Details	Requirements	Remarks
Track Gauge	1435 mm	Standard Gauge
Maximum Width of Car body	3.4 Meter	For maximising the passenger/floor area

Details	Requirements	Remarks
Maximum Length over coupler of Car body	25 Meter	Optimised considering the platform length and passenger carrying requirement
Nominal Height of the Car body	4.5 Meter	Optimised considering the construction gauge and the tunnel height
Train Configuration	9 Car DMC-TC-MC-MC-TC-MC-MC-TC-DMC 12 Car DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC 15 Car DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC	This is preferable configuration. During project execution different configuration may be selected provided that the configuration will meet all the performance requirements.
Coach Type	Executive Coach with 2+2 seating Normal Coach with 2+3 seating Normal Coach with pantry and 2+3 seating Normal Coach with PRM facility and 2+3 seating	
Seating Capacity	Executive Coach- 44 Seats Normal Coach - 75 Seats	
Doors External	2 Numbers on each side of the Car	In Driving Car only one door per side of the car for passenger movement and separate door for driver entry into the driving cab
Doors Internal	One Number on each end of the Car	In Driving Car only one door on extreme end of the car for passenger movement.

Details	Requirements	Remarks
Luggage Space	One at each car	One at each car for big sized luggage and side-line luggage racks for small/medium size luggage

9.1.8 Rolling Stock Performance & Safety Standards

Currently, we can categorise high speed lines on the market into three types:

- Extreme high speed (over 300km/h): running mainly on dedicated high-speed lines. Several series are already operating, and some are under development.
- High speed (240km/h-300km/h): commonest type of high-speed train operated in the world today and running mainly on dedicated HS line.
- High speed for conventional lines (200km/h-250km/h): running on both dedicated high-speed line and upgraded conventional line.

The proposed SilverLine belongs to the third category as per the traffic requirement of the corridor.

Usual performance shall consider the line profile and operation requirements such as average commercial speed, dwell time and maximum speed.

The SilverLine Rolling Stock is powered by electric traction. The electrical energy required to traction and braking is provided via an overhead catenary distributing 25 KV, 50 Hz AC supply. The acceleration is achieved through traction chain involving traction inverter and traction motors. The deceleration is achieved through a combination of the regenerative braking using traction chain and pneumatic braking using bogie mounted brake equipment in normal operational braking. In emergency braking only pneumatic braking is proposed to decelerate the train. As per the operational requirement of SilverLine, the following performance parameters are proposed.

Given that the main aim of SilverLine is to reduce travel time between two points, acceleration and deceleration performance is a particularly important factor to be taken into account for trains running short distances, having many stops, or running on lines with speed restricting factors such as curves.

9.1.8.1 Maximum Speed

For the proposed SilverLine corridor between Thiruvananthapuram and Kasaragod has a maximum proposed operational speed of 200 kmph and design speed of maximum 220 kmph. The Rolling Stock and associated systems shall be capable of running the train at 200 kmph Speed. Speed restrictions at curves as per specified value will be followed for at most passenger comfort.

9.1.8.2 Acceleration

Proposed Rolling Stock shall have an initial acceleration not less than 0.6 m/sec^2 with an average acceleration not less than 0.25 m/ sec^2 up to 200 kmph. The acceleration value has an impact in the traction motor capacity. The acceleration shall be jerk limited in all speed range. The acceleration shall be sufficient to overcome the aerodynamic resistance at 200 kmph speed on grade operation. The train shall achieve 200 kmph speed from standstill in 250 seconds on level track operation.

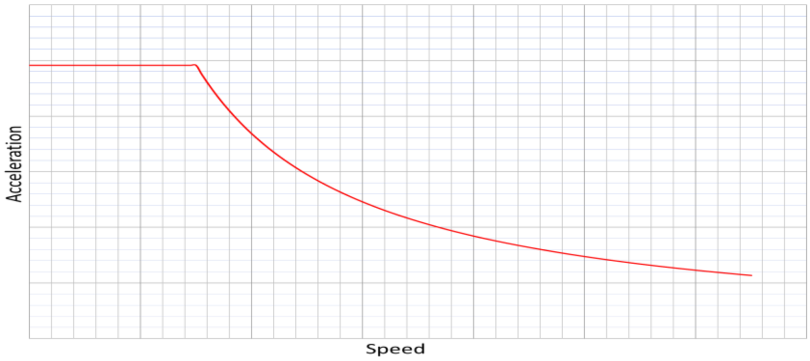


Figure 9-6: Typical Acceleration Curve

9.1.8.3 Deceleration

The deceleration value is defined for emergency braking and normal operational braking (service braking). Higher deceleration for emergencies should be taken into account when increasing safety. The proposed deceleration values are listed below.

- Emergency Brake Deceleration- 1.3 m/sec^2
- Service Brake Average Deceleration- Not less than 0.6 m/sec^2
- Emergency Braking Distance <1300 m
- Service Braking Distance (200 kmph to 0 kmph) < 3000 m

All the decelerations shall be jerk limited. Dynamic performances of the Train are proposed to follow EN 13452-1.

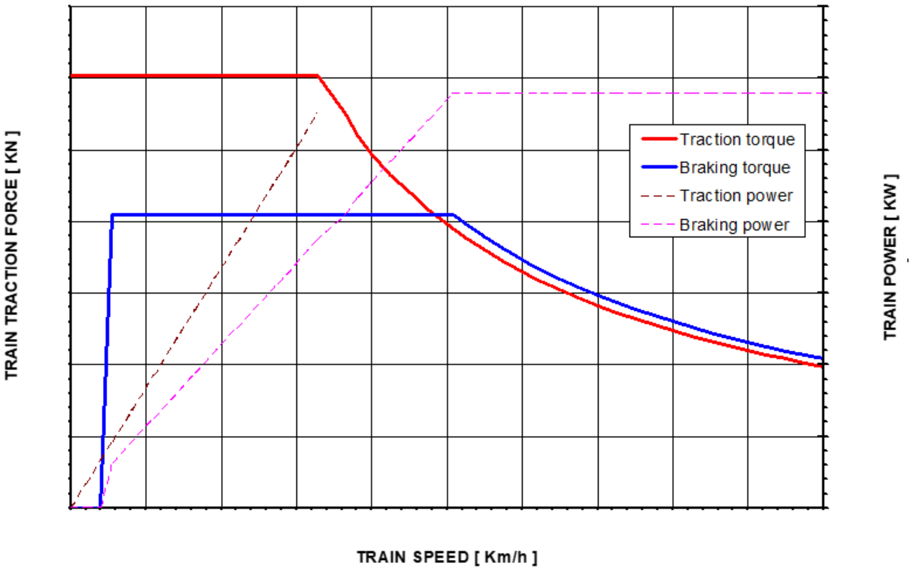


Figure 9-7: Typical Traction and Regenerative Braking Performance Curves

9.1.8.4 Axle Load

Since the SilverLine is a new project, involving laying of a new line, there is no constraint of an existing track with a specified axle load. The system can be designed and constructed to any desired axle load. Keeping the axle load to the bare minimum is however always desirable, to reduce cost of civil infrastructure. It has been estimated that the maximum axle load of the proposed coaches will be 16 tonnes as the passenger occupancy is only by seating type. This has been estimated by consulting coach manufacturers, carrying out broad calculations and examining the weights of similar coaches in use. The power equipment viz. converter-inverter, traction motor and transformer etc. shall be distributed amongst the motor and trailer coaches for uniform weight distribution and to keep the axle load of individual coaches within limit.

9.1.8.5 Power Requirement

The requirement of power shall be minimal so that the energy consumption is minimum to the extent possible. Traction motor and other traction chain equipment shall be of higher efficiency type. The acceleration of the train shall be chosen in such a way that the traction motor is optimally utilised. Regenerative braking shall be used to the maximum speed range possible. Power requirement for different high speed trains are listed in **Table 9-12**.

Table 9-12: Power Requirement References

Series	ICE-4 Germany	Trenitalia-Italy	Virgin-UK	CRH5A-China
Type	EMU	EMU	EMU	EMU
Speed(kmph)	230	250	200	250
No of cars	7 Cars	7 Cars	9 Cars	8 Cars
Power Requirement	4600 kW	5600 kW	5500 kW	4950 kW

The approximate power requirement totalling traction system power and auxiliary supply system power is ranging from 5000 KW to 6000 KW for a 9 Car train configuration.

9.1.8.6 Current Collection

Contact performance should be excellent for high speed current collection and for preventing excessive contact wire and contact strip wear. It should be noted that replacing contact wires will generally be costly than replacing contact strips.

RS technology for stable current collection must aim for low contact loss rates avoiding excessive stress on contact wires and low contact strip wear by reducing arcs. Contact loss can be reduced by contact strip mass reduction, mechanical design of the pantograph mechanism and contact strip, and stabilisation of contact strip aerodynamic lift.

9.1.8.7 Ride Comfort Standards

Choice of proper primary and secondary suspension is fundamental for ensuring ride comfort. The ride comfort of the Rolling Stock shall conform to the prevailing statutory requirements in India. The suspensions of the Bogie, dampers and the central pivot shall be suitably designed to reduce the lateral and the vertical accelerations of the Bogie and the Car body.

Reducing elastic vibration depends very much on how stiff the car body shell can be made. The natural frequency of elastic vibration must not coincide with the operational speed frequency.

SilverLine train should be airtight to avoid exposing passengers to extreme pressure fluctuations during the running in tunnel or crossing with another train. Air tightness is particularly essential for SilverLine trains running through tunnels. The whole car body including doors must be well sealed for air tightness.

Suitable ventilation system along with the air conditioning units shall be provided to control the pressure inside the trains in tunnel sections.

The pressure variation inside the train shall conform to UIC 660 standard.

Globally, the unbalanced lateral acceleration preferred as 1 m/sec^2 and maximum 1.5 m/sec^2 for unavoidable conditions in the Rolling Stock at the floor level. The vertical acceleration shall be less than 2% of gravity for passenger comfort.

9.1.8.8 Aerodynamic Standards

Aerodynamic resistance plays an important role in the performance of the vehicle in terms of speed and acceleration. It also plays an important role in the passenger comfort in high speed train application. The surface area of the Rolling Stock determines the aerodynamic resistance to the train movement.

Smoother body shape, i.e. flat window, flat door, covered gap between cars, aerodynamic protuberances, covered protuberances, flat undercovers etc, help to reduce resistance. The aerodynamic nose mounted in the front of the car reduces the aerodynamic resistance, reduces the impact tunnel pressure waves and prevent flying objects to hit the windshield. The train shall be designed to restrict the maximum allowable instantaneous pressure change on a person’s ear to 1.5 psi (10 kPa).

In addition to these measures are to be taken to cover the underframe equipment and roof equipment to reduce the aerodynamic resistances.

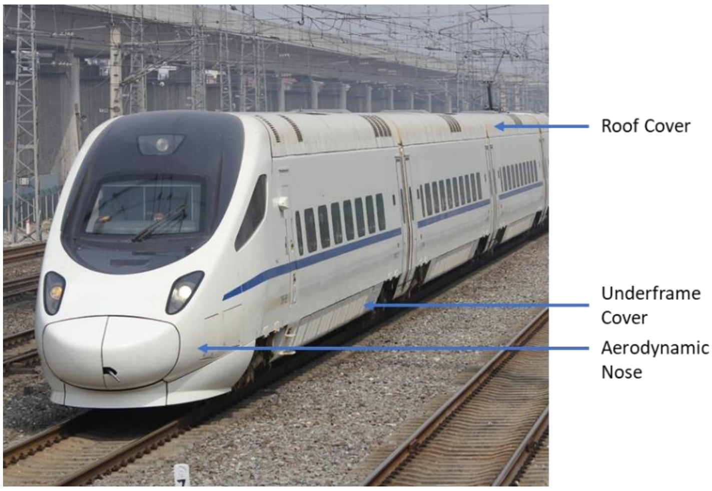


Figure 9-8: Aerodynamic Features

9.1.8.9 Fire Standards

Materials used in SilverLine should be non-flammable or at least flame resistant. They should be also light weight, environmentally friendly, and economically feasible.

All materials and equipment used in the Rolling Stock must be fire resistance conforming to EN 45545 series standards with applicable hazard level of HL2. In addition to the above standard, the Rolling Stock shall generally conform to NFPA 130 standard.

Minimum two numbers of fire extinguishers shall be provided in each coach. In each coach and cubicles, heat and smoke detecting units is to be provided. The heat and smoke detection operation shall be properly communicated to train control system and air conditioning system to prevent the spread of the fire and smoke.

Passenger Evacuation rules should comply with regulations in force in India. For fast evacuation, passenger doors of suitable size and breakable windows are considered. The passenger evacuation shall generally conform to GMRT 2130 and EN 45545 series standards.

Side evacuation is proposed for the Rolling Stock. Portable ladder for providing the track level access shall be placed in the Rolling Stock near the doors identified as emergency evacuation doors. The emergency doors shall be operable by the passenger in case of evacuation. Similarly, at least two emergency evacuation windows are to be provided in each car.

9.1.8.10 Running Stability

Globally the semi high speed trains must be stable at 110% of the maximum operational speed. Notwithstanding this percentage margin, Rolling Stock must prove it has a safety margin for stable running at maximum operating speed.

The Bogie design shall stipulate the offloading parameter, derailment coefficients and Y and Q forces to maintain the running stability.

9.1.8.11 Environmental Standards

The SilverLine Rolling stock shall conform to the Environmental requirements on EMC, impact to environment, noise level, waste treatment and impact of the interior materials to human health. Dangerous materials shall be avoided (like asbestos, cryogenic liquid, etc). All the waste of EMU shall be discharged properly at fixed place. Waste tank shall have enough capacity to satisfy this requirement and avoid pollutions along the line. Materials used in manufacturing the Rolling Stock shall be recyclable to the extent possible.

Reduction in CO_2 emissions from HSRS is proportionate to the reduction in energy consumption. Various methods exist to reduce energy consumption: reduction of power unit energy loss, use of regenerative braking and reduction of running resistance. Eco-driving may be incorporated into timetabling through Signalling & Train Control system.

Ground vibration is depending on the axle load of the Rolling Stock. Reduced axle load of 16 Ton will reduce the ground vibration.

The Rolling Stock shall be designed considering the prevailing climatic and environmental conditions in the corridor. Typically, in India ambient temperature at 0 to 50^o C and humidity at 90% or over is required to reflect the environmental conditions and salty atmospheric conditions during hot seasons as well as concentrations of SO_2 and particulate matters suspended in the atmosphere. Environmental conditions for the equipment on board the coach shall conform to EN 50125-1.

9.1.8.12 Noise Standards

Materials and structure design for passenger cars should aim to dampen or cut noise emanating from the floor, windows, walls, ceiling and eliminate sources of noise generally. In the case of EMUs, noise abatement measures are especially important since a large number of noisy components are located beneath the passenger saloon. Air conditioning systems and forced ventilation systems are also major noise sources both at component level and because of the air ducts.

External SilverLine train noise is classified as rolling noise, noise from mechanical parts like bogie parts, noise from electrical components like air conditioning and blower motors, contact noise from the pantograph, and aerodynamic noise. Aerodynamic noise forms one of the main noise sources on high speed train according to research and tests so far. It stems from the pantograph itself, roughness of the car body, gaps between cars, the nose, the space around bogie, and so on. This can be reduced with smoother surfaces, using noise dampers, using aerodynamic parts, adding parts assisting smooth air flow especially around car gangways and around bogies, fitting noise insulation panels around pantographs and bogies etc. To reduce the pantograph induced noise, number of pantographs shall be optimised.

Rolling noise may be reduced through measures applied at wheel/rail interaction level and using wheel flange lubrications. As a reference, the guidelines for noise and vibration issued by RDSO shall be followed during the project execution.

Typical limits of noise based on reference projects are provided below.

a. In stationary condition, the noise level inside the coach and the cab shall not exceed 68 dB (A) with all auxiliary equipment operating at maximum noise level. The noise level shall be measured in the coach along the centre line of the coach at a height between 1.2 and 1.5 meters above the floor and at a distance not closer than 0.6 meters from the end of the coach. The measurement shall be done as per ISO 3381. The noise level outside the coach shall not exceed 68 dB (A) with all Auxiliary Equipment operating. The noise level shall be measured at a point 7.5 m from the coach centreline at a point between 1.2 meter and 1.5 meter above the rail level. The measurement shall be done as per ISO 3095.
b. Inside a train moving at maximum permissible speed, the noise level must not exceed 72 dB (A), measured in the same manner as described above. The noise level outside the coach when the train is moving at the maximum permissible speed shall not exceed 85 dB (A) with all auxiliary systems operating. The noise level will again be measured in the same manner as described above.

9.1.8.13 Electromagnetic Compatibility

Rolling Stock shall be such that the vehicles shall not interfere with the proper or safe operation of the vehicle external systems, or any wayside external systems, or equipment used by the public such as cellular phones, hospital, airport etc. It should be noted RS must be designed to avoid harmonics which sometimes affect Signalling & Train Control systems.

The Rolling Stock shall conform to the EMC standards EN 50121 series. The electromagnetic compatibility of all onboard electronic equipment shall meet the relative regulations in the set of norms IEC 61000.

9.1.8.14 Summary of Performance Standards

Table 9-13:Summary of Performance Standards

Details	Requirements	Remarks
Maximum Speed	Operational-200 kmph Design- 220 kmph	
Initial Acceleration	Not less than 0.6 m/sec^2	The average acceleration up to 200 kmph not less than 0.25 m/sec^2
Average Deceleration	Not less than 0.6 m/sec^2	Emergency Brake Deceleration- Maximum 1.3 m/sec^2
Axle Load	16 Ton	

9.1.9 Technical Details of Rolling stock

The engineering concepts of the proposed SilverLine Rolling Stock is detailed in this section. There are many manufacturers in India and all over the world, manufacturing Semi high-speed trains. Each manufacturer will have his own specialized technology and features for the coaches and therefore we should not lay down in detail what technology the manufacturer should use, as this would limit competition in supplying the EMUs. Below detailed engineering details covers the concepts and bare minimum requirement without orienting any specific manufacturers. These requirements are based on safety, comfort, costs, ease of maintenance and contemporary technology. Detailed specification shall be created during the project execution stage.

9.1.9.1 Rolling Stock Car body

9.1.9.1.1 Structure

Well proven and classical solutions shall be proposed in order to facilitate maintenance activities and to provide a low-cost vehicle. Rolling Stock car body should be manufactured with Aluminium. The type of Aluminium or Aluminium alloy selection and the process of welding selection shall be done in such a way to reduce the weight of the car body without affecting the strength requirements of the car body.

Body shell will be designed according to UIC 566 and EN 12663. The profile of the car body should be designed to reduce the aerodynamic resistance, maintain the air tightness and reduce effect of the pressure waves. The body panelling must have resistance to the tractive and braking effort of the coach as well as to any impact and accidental damage. No materials likely to cause environmental damage during the manufacture, maintenance, operation and disposal of coaches shall be used. To increase ride comfort, the structure should be as stiff as possible in the both case of bending and twisting.

Lifting and jacking points shall be provided on the vehicle car bodies to comply with the vehicle maintenance principles. The lifting and jacking points shall be easily accessible to facilitate re-railing in the event of a derailment.

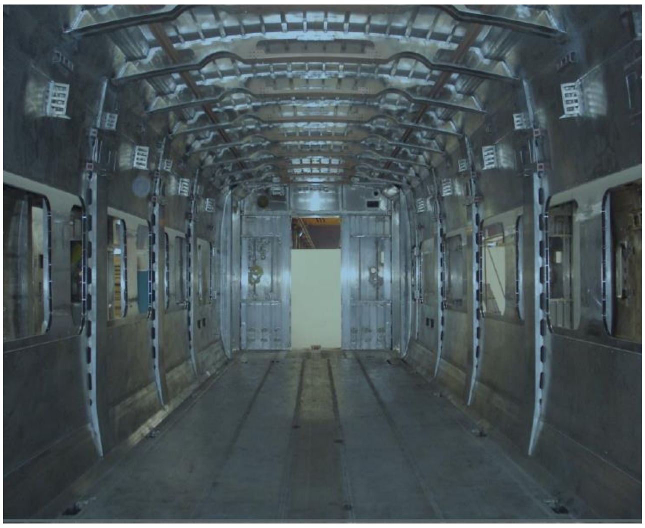


Figure 9-9: Typical Aluminium Car Body Shell

9.1.9.1.2 Crashworthiness

The vehicle body shall protect occupants in the passenger compartments in the event of a collision between two trains or between a train and a wayside obstruction. This protection shall be provided by means of energy absorption devices and controlled, progressive, plastic deformation and/or buckling of the car body ends.

The car structure and its supplemental energy absorption devices shall be designed to protect passengers and driver, and not permitting one vehicle to over-ride another. The car body crashworthiness shall correspond to requirements in EN 15227.

The compression strength of the main car body structure enclosing the passenger compartment shall be greater than the compression strength of the car body ends in such a manner that the main structure shall neither collapse buckle nor plastically deform until the sacrificial elements of the car body-ends have been permanently deformed.

The coach should be of anti-telescopic design with anti-climbers. The coach structure shall be designed to minimize accelerations transmitted to passengers, by absorbing any collision energy, and must prevent one vehicle to over-ride another, nor to telescope one into another.

9.1.9.1.3 Driving Cab and Driver Desk

Driver’s cab is to be equipped at the two ends of the train for drivers. Driver’s cab shall be designed based on ergonomic principle and in accordance with UIC 651 standards. The equipment inside the driving cab must ensure safe driving and control of the Train by only one driver. The driver desk shall be designed for ease of operation, prevention of operational errors, ensuring sufficient front vision, reducing driver fatigue, noise abatement and ensuring sufficient space for the driver. The driving cab shall be provided with a safety system that will prevent any non-authorized person controlling the vehicle. A door on each side of the driving cab for access from the outside shall be provided.

Normally in addition to the driver desk control items, driver seat, windshield with wiper, sunblind, driver foot plate etc. shall be provided for driver ease of operation.

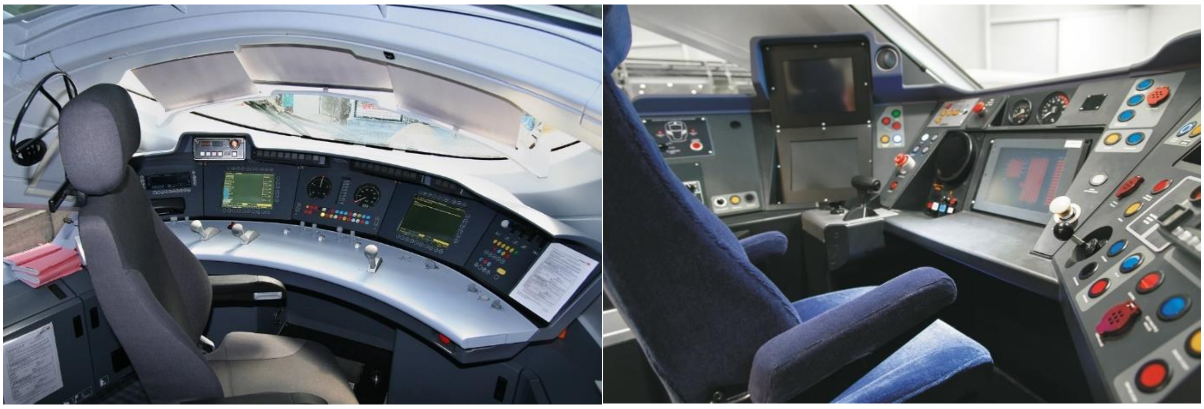


Figure 9-10: Typical Driver Desk Layout

9.1.9.1.4 External Livery

The external portion of the car body shall be aesthetically pleasing. The manufacturing shall define suitable tolerance for the variation in the flatness of the car body. In addition to this, during the project execution it may be decided to provide external painting or glued livery as per the requirement at that time. The painting or external livery shall conform to all the applicable fire standards.

9.1.9.1.5 Other Car body Components

An open gangway shall be provided at all intermediate ends of the cars. The gangway shall be designed to reduce the noise inside the car. Similarly, it shall be airtight to guarantee the tightness of the train. The front coupler may be sealed to reduce the air resistance with openable hatch.

To guarantee flexible train services, there must be a connector system for easy coupling and decoupling for both mechanical and electrical couplers There shall be front coupler and intermediate coupler provided. The front couplers are used for the rescue or coupled operation if it warrants. Intermediate couplers are provided to couple each car to form a train. It also helps in traction and braking force transmission. It takes the loads of intermediate car electrical and pneumatic connections. The couplers shall be capable of withstanding all operating forces experienced in normal operation, during maintenance operations, and in the event of a collision.

A cow catcher or obstacle detector is required to provide under the front driver’s cab to move any foreign object lying on the track.

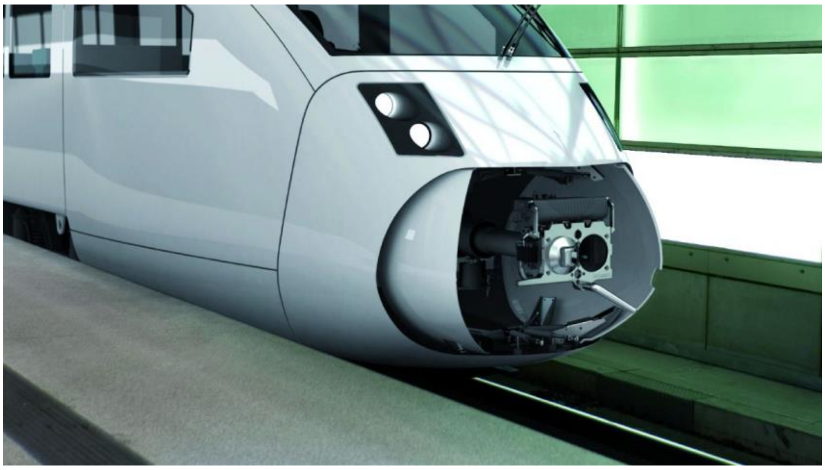


Figure 9-11: Front Coupler with openable cover

9.1.9.2 Rolling Stock Interior

9.1.9.2.1 Interior Aesthetics

Cabin design is directly related to passenger comfort and affects an operator’s image and profitability. The Interior components of the Rolling Stock plays vital role in offering comfort and safe journey to passenger and crew. State of art of Interior design shall be adopted during the project execution stage. The vehicle interior shall facilitate the mobility impaired passengers from having full accessibility to the transport system.

The interiors shall be aesthetically pleasing also. The interior components must be fire resistant and shall reduce the noise and vibration inside the Rolling Stock.

The interior floor covering shall be antiskid, firm, durable and aesthetically pleasing and it shall be easy for regular cleaning. The floor unit plays an important role in EMU type of trains in reducing the noise and vibration emitting from underframe equipment.

The ceiling shall be suitable for fixing the light luminaries and displays if required. The ceiling also provides support for fixing the air duct and the air conditioning diffusers.

9.1.9.2.2 Passenger Seats

Row type of seating is recommended for the passenger seating. There are two types of seats are recommended. One is executive type seat and the other is standard type seat. The seating capacity is covered in the performance section of this report.

In executive class 2+2 type of seating and in standard class 2+3 type of seating is recommended. The seat pitch in executive class should allow most people to stretch out their legs in front of them. Standard class seat provides knee space for the average individual even when the seat in front is reclined. Rotating type and Reclining type of seats are recommended for executive class seats and Reclining type of seats are recommended for normal class seats. Seats shall accompany with arm rest and footrest. Seat shall be provided with the flip down or flip up table.

Flexible type of seating and rotating type of seating for improving the comfort of the passengers can be considered as optional. If required, these types of seating can be specified during the project execution stage.

9.1.9.2.3 Windows

The windows of the car body sides and doors is intended to minimize solar gain and provide a satisfactory comfort level. On the outside, all windows shall be flush with the body side walls and doors surface to reduce the pressure fluctuations and to maintain the air tightness.

Emergency windows shall be identified in each car for the evacuation purpose. At least two emergency evacuation windows are to be provided in each car.

9.1.9.2.4 Luggage Racks

It is proposing to have luggage rack on one end of each car as the SilverLine corridor is connecting major cities and airports in Kerala. In addition to the luggage rack on one end of the car, each car shall have two rows of luggage rack on side wall of the interior placed above the seat for small items.

9.1.9.2.5 Pantry Requirement

For the SilverLine trains, in seat type of catering is proposed. As the time required to travel from Thiruvananthapuram and Kasaragod is less than four hours, a full-fledged pantry with live kitchen is not recommended. An area for pantry is ear marked in one of the coaches for the in-seat catering service (using trolley or carrying). This pantry may require as a minimum heating devices, refrigerator and cash locking devices.

9.1.9.2.6 Toilets

In each car of a train one modern type of toilet is proposed. In one of the cars, a universal toilet is proposed for the persons with reduced mobility (PRM). The associated PRM facilities are to be provided on the same car where the universal toilet is proposed. For more comfort, there may also be baby-changing tables provided in the toilets. A mix of eastern and western type of toilets may be adopted.

Biochemical processes have recently been developed for the disposal of sewage which shall be adopted for the proposed Rolling Stock. This solution may turn out to be both eco-friendly and facilitate operations. The water and waste tank capacity related to toilet and services shall be decided during the detailed design of the project.

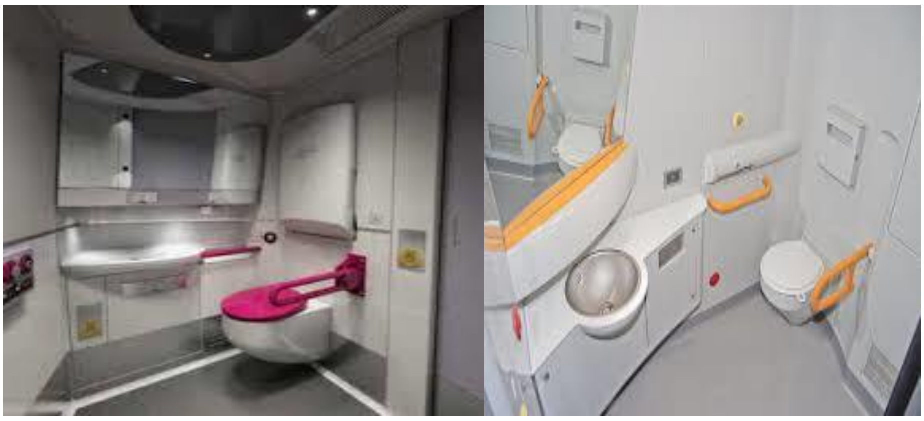


Figure 9-12: Typical Universal Toilets for Semi High Speed Trains

9.1.9.2.7 Facilities for Persons with Reduced Mobility (PRM)

One car in each train shall be provided with the facilities for the persons with reduced mobility. Wheelchair areas are to be marked specifically in this car for the wheel chaired passengers. Universal toilet shall be provided in this car for the persons with reduced mobility. Holding handles and other necessary accessories in the wheel chaired area are to be provided.

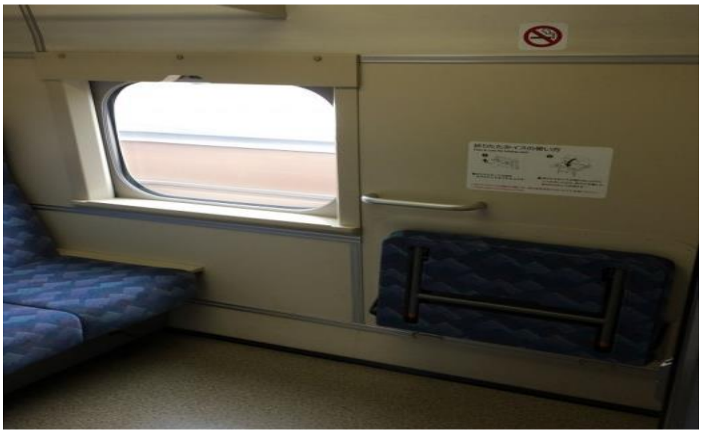


Figure 9-13: Area for Wheelchair

9.1.9.3 Propulsion System

In recent years, thanks to progress in the field of power electronics, high speed trains have gradually been equipped with new technology, controllers, devices and motors which have improved energy efficiency and reduced maintenance costs. AC motors with IGBT / VVVF controllers are now more or less mainstream. The most common type currently in use - AC motors - include induction motors and synchronous motors.

For the SilverLine Rolling Stock, Variable Voltage variable frequency (VVVF) type IGBT based propulsion system is proposed. The traction motor shall be three phase asynchronous type motor or permanent magnet synchronous type. The propulsion system shall deliver the tractive power as well as contribute in braking effort by doing regenerative braking.

The input power to the propulsion system is provided through overhead catenary system at 25 KV, 50 Hz AC supply. The power is collected by the pantograph mounted on the roof. A typical traction chain is shown in **Figure 9-14**.

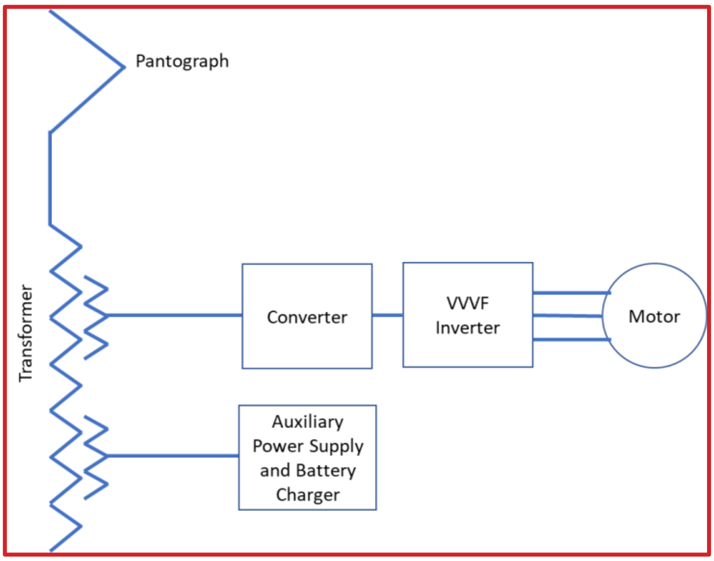


Figure 9-14: Typical Traction Chain

In 9 car train configuration, 6 cars are provided with propulsion system and associated motors for the tractive and regenerative brake purpose. The percentage of motorized cars is maintained in 12 and 15 car train configurations. Redundancy shall be built among the motorised cars in case of failure of any propulsion system in motorized cars.

Care shall be taken to mount the equipment in traction chain to underframe to the extent possible in order to lower the centre of gravity and to reduce the aerodynamic resistances.

The power to the propulsion system is collected through pantograph by touching the catenary. The mechanical system of pantograph and pantograph shall be suitably designed to increase the current collection, to reduce the arc noise and to reduce the friction. During project execution stage appropriate measures such as covering of the pantograph mechanical system for reducing the aerodynamic resistances shall be considered.

A circuit breaker along with earthing provision shall be provided. An underslung transformer shall be provided for supplying the traction and auxiliary systems on the train. Transformer shall be cooled as per the requirement.

Four quadrants controlled VVVF based Converter inverter unit is proposed for driving the traction motors. Four quadrants Converter inverter unit manages the propulsion as well as regenerative braking functions. 3 Phase Traction motor shall be mounted on the underframe or on the Bogie. The rating of the traction motor and traction chain shall be evaluated to meet he performance requirements of the Rolling Stock.

As a step towards energy saving measures, highly efficient components shall be used in the traction chain. The regenerative braking shall be used to maximum extent possible from 200 kmph to 0 kmph range.

Special care must be taken on selecting the converter inverter and the motor as these components plays important role in contributing noise and vibration in the Rolling Stock.

The traction inverter shall generally conform to IEC 61287 standard and traction motor shall generally conform to IEC 60349 standard.

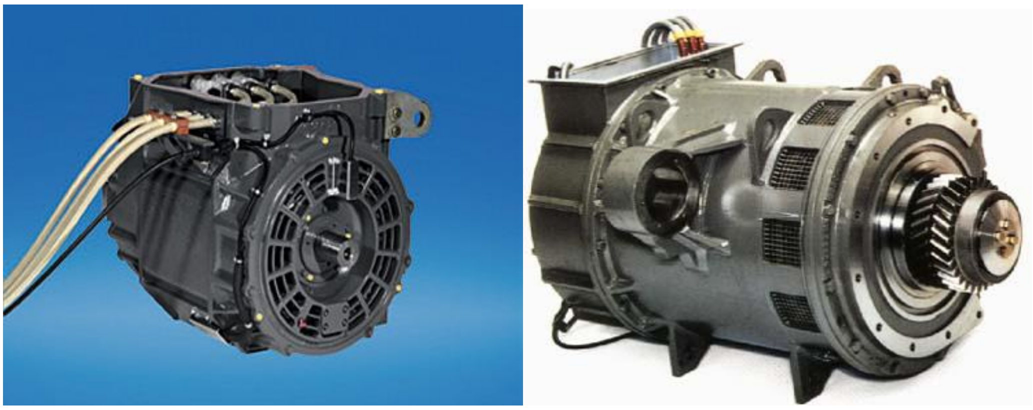


Figure 9-15: Traction Motors

Brake resistor may be used in order to dissipate the regenerative energy in the case of non-receptive catenary.

9.1.9.4 Brake System and Air Supply System

9.1.9.4.1 Brake System

The brake system shall meet UIC requirements and EN 13452 for air brakes on EMU type of passenger vehicles, operating at speed up to 200 kmph. Blended braking using regenerative braking and pneumatic braking is proposed for SilverLine Rolling Stock operating at 200 kmph. The braking system of the EMU consists of braking control system, electric regenerative braking, pneumatic braking system electronic antiskid unit and basic braking devices, etc. The following types of brakes are proposed in the EMU trains

- Electric regenerative service brakes
- Electro-Pneumatic (EP) service friction brakes

- Brake-pipe controlled back-up brake system
- Fail safe emergency pneumatic brakes
- Spring applied, pneumatic release parking brakes.
- Holding Brake

Regenerative braking is essential to reduce energy consumption and may even be used instead of mechanical brakes for doing the service braking of the train, to help reduce maintenance costs related to the latter. Mechanical brakes however would still be necessary as a backup system in an emergency.

For the service braking from 200 kmph shall use regenerative brake to the maximum extent possible. If there is any deficiency during the regenerative braking, pneumatic friction brakes shall be used. For the emergency braking, pneumatic brakes only used. The brake system effort and pneumatic pressures shall be designed to meet the performance requirement of the train.

Disc/Tread or mix of disc and tread type brake system is proposed for the SilverLine Rolling Stock considering the thermal stress during braking. It can be wheel mounted or axle mounted as per the requirement of the design. Associated pneumatic system comprising pipes, reservoirs, compressors etc shall be provided.

Brake Control Electronics shall be advanced computed based devices. It shall be able to manage the blending of the regenerative braking and the pneumatic braking. Similarly, these electronics devices shall continuously monitor different parameters and status of train and shall protect the train from unsafe operation during braking.

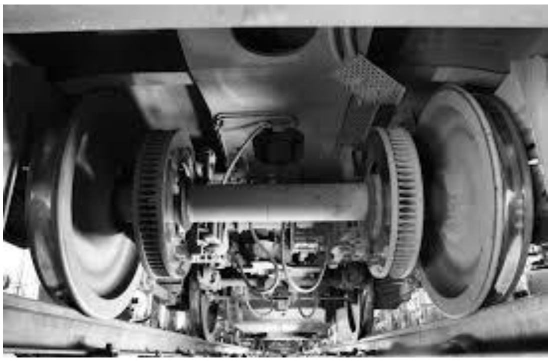


Figure 9-16: Axle mounted Disc Brake System

All type brakes in the train shall be train operator initiated or brake system initiated. None of the brakes are proposed to be initiated by passengers.

Any other types of braking system shall be proposed if the braking system is safe and advantageous compared to the proposed system

Reliable Wheel slide protection and anti-skid protection devices shall be used in the train. It shall protect the train during regenerative braking as well as pneumatic braking. The Wheel Slide protection shall be automatic and will interface with automatic train protection, auxiliary warning system and train protection and warning system equipment.

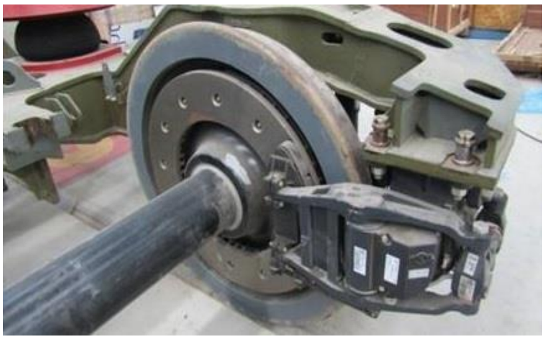


Figure 9-17: Wheel mounted Disc Brake System

9.1.9.4.2 Air Supply System

In addition to brake system, there shall be a pressurised pneumatic supply system in the train. The pneumatic system pressure is maintained by compressors provided on the underframe of the train. In addition to Brake system, the pneumatic supply may be used for the following functions also;

- Pneumatic suspension system
- Toilet system
- Warning horn
- Pantograph and main circuit breaker
- Flange lubricating device
- Coupler and hatch;

9.1.9.5 Auxiliary Systems

9.1.9.5.1 Auxiliary Converter

An IGBT based Auxiliary converter shall be provided in the train to cater the auxiliary loads in the train. The power supply to the Auxiliary converter shall be fed by the transformer. The Auxiliary Converter shall be preferably mounted on the underframe. The auxiliary converter shall cater the loads such as air conditioning system, air compressors, cooling fans, pantry equipment, lightings etc. In addition to the listed load, the auxiliary converter shall provide the DC 110 V supply to all the control devices on the train through the battery charger.

The battery charger shall charge the battery units on the train as per the requirement.

9.1.9.5.2 Battery Units

Low maintenance type battery units shall be provided on the Rolling Stock for managing the emergency conditions. The Battery units shall be fire resistant and shall be designed to take the electric loads during the emergency conditions. The battery units shall support the electrical load requirements as per GMRT 2130. The battery units shall be preferably mounted on the underframe of the Rolling Stock. The following loads shall be minimum catered as per Table 9-14.

Table 9-14:Details of Emergency Back up

System maintained	Time
Emergency ventilation in all Cars including Driving Cabs	2 hours after the loss of OHE power
Communication system	2 hours after the loss of OHE power
Emergency lighting & Toilet System	2 hours after the loss of OHE power
Train controls	2 hours after the loss of OHE power
Fire detection system	2 hours after the loss of OHE power
Emergency Door operation	2 hours after the loss of OHE power

9.1.9.5.3 Rolling Stock Lightings

Appropriate lux level, interior and exterior lightings shall be provided on the Rolling Stock as per the UIC standard requirements. LED type of energy efficient lights shall be used in Rolling Stock.

Interior lighting shall be designed for passenger comfort. Saloon lights shall be provided on the ceiling with pleasing design. Reading lights on executive coach may also be considered. Driver cabin shall be provided with suitably designed lux level lights which will make the driver operation hustle free. In addition to the above, the internal lighting for cab and passenger's area shall comply with EN 13272 or equivalent standard. Both direct and indirect diffused lighting with minimum glare and individual reading lights may be provided

Exterior lights include, head lights, marker and taillights and other indicating lights. The head lights shall be durable and reliable suitable for elevated, at grade and tunnel operations. As an energy saving measure, the internal lights may be controlled according to the external light lux level.

Emergency lights shall be managed using the battery supply. Emergency lights shall be available minimum on passenger saloon, toilet and driver cabin.

9.1.9.6 Door Systems

The doors shall perform the following functions:

- Prevent access when inappropriate,
- Allow normal transfer between platform and vehicle,
- Allow transfer in an emergency situation.

External access Doors shall meet the requirement of EN 14752 or equivalent standard.

9.1.9.6.1 External Access Doors

Each car of train is proposed to have four sliding plug type external access doors (two on each side of car), except the driving motor car which will have two doors on a car, for the boarding and deboarding of passengers. The side doors shall be plug type to maintain the air tightness and to reduce the air resistance. The side doors shall be operated electrically with all the safety interlocks. It is proposed to have clear opening width of 800 mm considering the passenger traffic and luggage size. The doors shall meet the requirements of Persons with reduced mobility (PRM). All the doors shall be able to operate from inside by the passenger in emergency with proper authentication. Battery supply shall be sized to cater the operation the doors in emergency.

9.1.9.6.2 Internal Access Doors

Passenger operated internal access doors shall be provided on each end of the car near the gangway for easy movement of passenger and crew in between the cars. It shall be designed to reduce the noise in the saloon. Similar, in DM Car, a partition door shall be provided for accessing the saloon from cab by the crew during operation and maintenance with appropriate interlocks.

9.1.9.6.3 Toilet Doors

Hinged type toilet doors are proposed for the normal type of toilets. For the universal toilet meant for the PRM passengers, electrically operated doors may be considered.

9.1.9.6.4 Cab Doors

Cab Doors shall be provided on each side of the DM Car for accessing the cab by the crew and maintenance staff. It shall have proper locking system so that unauthorised persons will be prevented from entering to the cab.

9.1.9.6.5 Entrance Steps

In the case of large gaps between the platform and the floor of the train, automatic operated extendible steps may have to be fitted for better accessibility. This can be considered as optional and shall be finalized during the detailed design of the project. It shall be meeting all the requirement of PRM passengers.

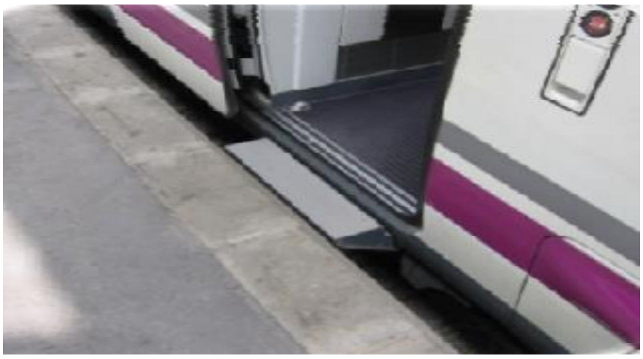


Figure 9-18: Typical Extendable Step

9.1.9.7 Ventilation and Air Conditioning

Installation of air conditioning is vital for passenger comfort. The power of the air conditioning component should be determined by the climate where the RS will be operated. Heat insulation of the car body is essential for the effective air conditioning. Air conditioning in the driver's cab is important because of the large window surface around the cab which transmits heat easily and in order to comply with driver working environment requirements. Driver cabs should have independent air conditioning.

Ventilation systems are also necessary to avoid large pressure fluctuations in the cabin in tunnel sections as well as during the emergency conditions.

The Rolling Stock each coach must be air-conditioned with minimum two roof mounted packaged unit type air-conditioning units in each coach. The Air-conditioning in coaches shall conform to EN 14750 or equivalent international standard. Interior temperature shall be 24-26°C at an ambient of 45-50°C. Relative humidity inside coach shall not be more than 65%.

In case of failure of air-conditioning, emergency ventilation should be provided. The emergency ventilation must supply at least 10 cubic meter per hour per person of fresh air to the coach. Provision shall also be made to shut off fresh air intake and recirculate the internal air of the coach, during an emergency condition, such as fire outside the train to prevent heat and smoke to be drawn into the coach.

Driving car shall be provided with independent air conditioning unit and shall maintain the inside conditions same as the saloon condition. Heating provision is not foreseen in Kerala climate. Hence heating is not recommended.

The air conditioning and ventilation shall be automatically controlled. However, driver intervention in the control shall be provided for the degraded mode of operations.

In the event of the failure of both air conditioning units on a car, an emergency ventilation system shall operate automatically to admit fresh air directly into car to maintain the required oxygen level, in accordance with ASHRAE 62.

The refrigerant used in the air conditioning units shall be eco-friendly in accordance with the “MONTREAL PROTOCOL” shall be used in the vehicle.

Proper design rules shall be followed in the design of the air conditioning units to reduce the noise and vibration to the saloon and driving cab. The selection of the compressor and other components of the air conditioning unit shall be done in such a way that the energy consumption is minimum as possible.

The air conditioners shall be roof mounted and mounting of the air conditioner on the car body shall smooth and curvy to reduce the air resistance. The air conditioning units shall be coordinated with the fire detection system in the Rolling Stock for appropriate action in the case of internal and external fire.

Figure 9-19: Air Conditioning Units

9.1.9.8 Train Controls & Electronics

Most of the high-speed trains are installed with on board control and information systems which control, monitor, diagnose and display the status of the train and its components. It may be able to integrate the Signalling & Train Control system and Communication system. These systems may be likened to the “brain” and “nervous system” of a train. The on-board control system shall be micro-processor based. Integration of functions may reduce the weight of train by reducing the amount of wiring and controllers for each component. The system should be robust against failure and adequately redundant given the key role it plays for operations.

The electronic control equipment should be protected against unavoidable EMI. As far as possible, the control and monitoring function shall be implemented by software to reduce hardware and cables. The control system must integrate the task of fault diagnostics and display in addition to control task. It should be capable of real time monitoring the status of all the vital equipment continuously and occurrence of faults. It shall also take appropriate protective action and shut down the equipment wherever necessary. Features of self-check, calibration and plausibility checks shall be incorporated in the design.

The vehicle control unit will have diagnostics computer to store all the relevant diagnostic data. Whenever a fault occurs affecting operation, background data with time mark along with GPS data shall also be captured along with the fault information on equipment and stored to enable proper fault analysis. There shall be facility to capture post trigger and pre-trigger background information. The vehicle control unit will also provide on-line, context sensitive trouble shooting guide to the driver in case of any fault

The bus architecture and the connected input output interfaces shall be designed to have redundancy. The safety required functions shall meet the safety integrity levels which may be defined during the detailed design.

All the status and information shall be recorded in event recorder. The data stored in the event recorder shall be stored in non-volatile read-write tamperproof memory with a First-In-First-Out (FIFO) capability, to ensure that the current data shall overwrite the obsolete data. The information and status required for the operation and maintenance shall be displayed on the GUI provided on the cab. The GUI shall be touch screen type for sending commands by the operating and maintaining staffs. Similarly, the onboard control system shall guide the operating and maintenance staff for the technical diagnosis and the troubleshooting.

The real time data sending from the onboard train control may be considered as an option. It may help in the preventive maintenance and in reduction in maintenance cost.

Subsystem such as propulsion, brakes, air conditioning etc., will have dedicated controllers. All these controllers shall meet the above detailed requirements. These controllers shall communicate seamlessly to the onboard main control electronics for smooth functioning of train.

9.1.9.9 Train Communication System

Train Communication System is used for the following communication:

- Between Train Operator and Operational Control Centre
- Between Train Operator and Passenger
- Providing information to passenger
- Between maintenance staffs

Driving cab of the cars will be provided with continuous communication with the Operational Control Centre and station control for easy monitoring of the individual train in all sections at all the time.

The passenger information system has the functions of passenger guide and travel information service and the contents include train number, arrival station, timetable, car number, operation speed, and internal and external temperature, etc. The Train Communication System will continuously advise the passengers of the next station, emergency situations if any, and other messages.

9.1.9.9.1 Announcement System

Manual Announcement system enables the Train Operator to give information to the passengers via the loudspeakers by the Train Operator/Train crew. Automatic announcement system is provided for giving the station information based on location to the passenger. Both type of announcement can be managed by Train Operator.

Emergency talk units are to be provided on each car for initiating communication from passenger to the Train Operator for assistance.

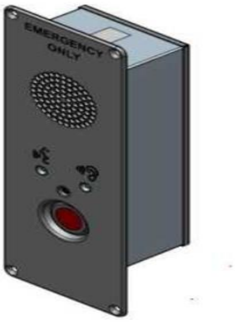


Figure 9-20: Passenger Emergency Talk Unit

9.1.9.9.2 Display System

There are internal display and external display proposed for the Rolling Stock. External displays may show the destination and intermediate stations, the train number and the coach number etc. The external displays may be placed outside the coach, nearby each passenger door for convenience. Internal displays shall be provided on each car for showing the next station information, speed of the train, timetable etc. These displays can also be utilized for commercial applications such as news and advertisements.

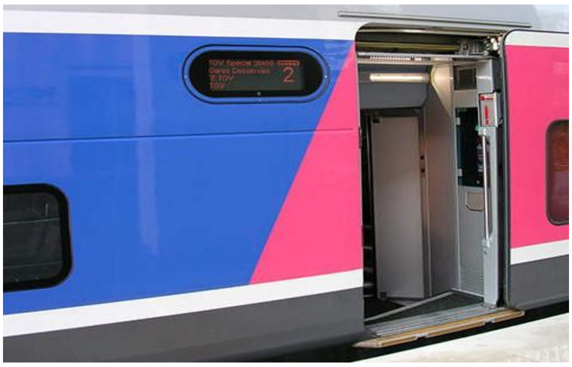


Figure 9-21: Typical External Display

9.1.9.9.3 Security System

Closed Circuit Televisions (CCTV) shall be provided on the Rolling Stock for the security purpose. The CCTV shall function appropriately during emergency situations also. Visual monitoring shall be provided in the driving cab for driver’s viewing when seated. It shall allow the driver to supervise any problem in the different passenger areas.

9.1.9.9.4 Ticket Checking Units

Ticketing checking online devices shall be considered as optional. The ticket checking devices will communicate to the fare collection system and provided appropriate feedback.

9.1.9.9.5 Entertainment System

Entertainment system such as movie playing screens and on-board Wi-Fi etc shall be considered. These services can be utilised for commercial applications as well. The layout of the video screens and media interface controls shall be designed during the detailed design. Seat mounted screens shall be provided on Executive coach and in other types of coaches Wi-Fi based entertainment system which can be accessed on personal smart devices shall be deployed.

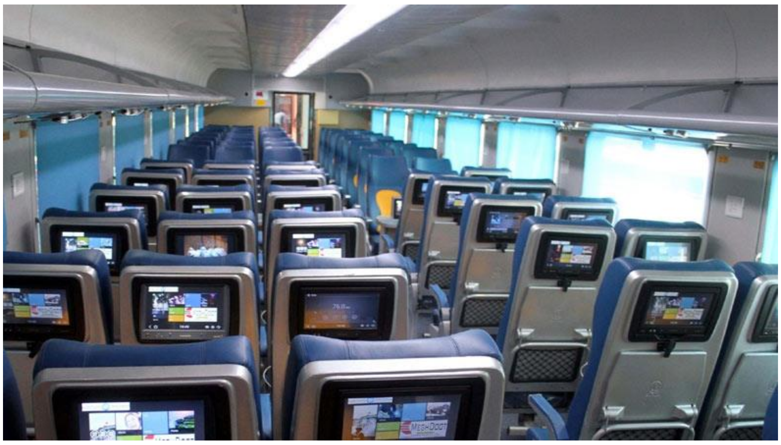


Figure 9-22: Entertainment System

9.1.9.10 Bogies

Two axle type Bolster less Bogies (Bo-Bo) are proposed for the SilverLine Rolling Stock. The weight of the Car is transferred through the air suspension system. There are two types of Bogies namely, Motor Bogies and Trailer Bogies. The bogie is one of the heaviest components on RS, which means that the weight of some parts may have to be reduced – such as bearings, axles, wheels, gears, brakes etc. so long as the level of safety or reliability is not affected. Important component of Bogie is the Bogie frame. It shall be manufactured from steel complying to EN 10025 standards. The structural design of bogie frame shall conform to BS EN 13749:2011-Railway Application-Methods of specifying structural requirement of Bogie frame. Wheel axle shall conform to EN 13979-1:2011&EN 13262/BS EN 13104 or equivalent AAR/JIS standards.

The bogie shall be capable of safe operation keeping the damping values positive, at all combinations of track condition, vehicle speed, co-efficient of friction, operating conditions, and loading. The bogie must be compatible with the track parameters specified in the chapter on track.

9.1.9.10.1 Bogie Suspension

Primary and Secondary suspension shall be provided on the Bogie. Air Spring type secondary suspension shall be adopted. Use of air spring at secondary stage is required to keep the floor level of the car constant irrespective of passenger load. Jerks from the track are also dampened inside the car body on account of the secondary air spring. The suspension system shall prevent excessive forces transmitted by wheels leading to track damage/derailment and/or unloading of wheels leading to risk of derailment. Appropriate vertical and horizontal dampers shall also be provided on the Bogie for maintaining the stability of the Bogie.

9.1.9.10.2 Wheels and Axles

The wheel profile shall be matching to the track profile selected. The wheels shall be suitable for the disc braking type application in the speed range of 200 kmph. The grade of the wheel material shall be selected based on the brake application and wheel wearing. The axle -wheel assembly shall be mounted on the bogie frame using axle boxes.

On the motor bogie, gear box shall be fitted directly on the axle. Suitable coupling system shall be provided in between gear box and the traction motor. Similarly, the axle-wheel assembly shall equip the disc brake assembly.

Wheel lubricating devices shall be provided on the Bogie for reducing the wheel friction and thus reducing the wheel wear and noise on the curves. Sensors such as temperature measuring of axle box shall be considered on the Bogies.

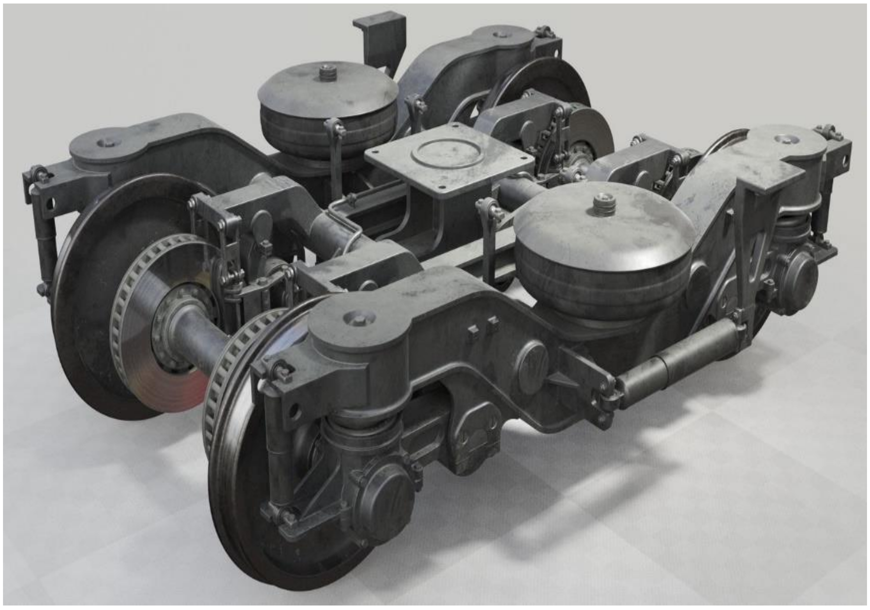


Figure 9-23: Typical High Speed Bogie

9.1.9.11 Summary of Rolling Stock Technical Standards

Table 9-15:Summary of RS Technical Standards

Details	Requirements	Remarks
Car body	Aluminium Material	Light Weight
Interior	Modern Aesthetical type with two types of cars • Executive Class • Standard Class	Facilities such as luggage racks, toilets, pantry and facilities for persons with reduced mobility etc are proposed.

Details	Requirements	Remarks
Propulsion System	IGBT Based VVVF Controlled Propulsion system working on 25 KV AC Catenary supply	Energy Efficient System shall be adopted
Brake System	Blended Brake system comprising Regenerative Braking and Pneumatic Braking is proposed.	For Emergency Braking only pneumatic braking is used.
Auxiliary System	Auxiliary Converter for auxiliary electrical loads Battery for emergency back up Lights for saloon, cab and driving	Energy Efficient System shall be adopted. Battery shall be sized to cater the emergency conditions
Door System	External Access Door Internal Doors Toilet Doors Cab Doors	Automatically operated external step for bridging platform and train may be considered as optional.
Air Conditioning	Two air conditioning units per each car.	Separate air conditioning unit for Driving Cab
Train Control	Train Control Electronics communicating to each sub system on board.	Reliable electronics shall be provided. Applicable Safety requirements shall be validated.
Train Communication	Announcement System, Display System	Entertainment system is considered.
Bogies	Double Axle type Bogies Motor Bogies & Trailer Bogies	Air spring type secondary suspension for comfort is proposed.

9.1.10 Passenger Amenities

This section details about the passenger amenities provided on the Rolling Stock for the comfort of the passengers.

- Seats- Comfortable seats with hand rest is provide. The seats are of rotating and reclining type seats.
- Lights- Pleasant white type lights are proposed in the saloon. Reading lights are also proposed for passenger requirement.
- Air Conditioning- The saloon area is air conditioned with optimum temperature. The saloon is supplied with sufficient air conditioning and air conditioning system manages the pressure inside the saloon.

- Toilets- Two toilets per car are proposed with all modern facilities.
- Food and Beverage services- Portable trolleys will serve the food and beverages to the passengers.
- Luggage racks- Luggage racks for large sized bags and small sized bags are provided in each car.
- Charging facilities- Mobile and Laptop charging facilities with USB are proposed.
- Wi-Fi- Passengers can avail the Wi-Fi provided on the train during the journey.
- Information System- Information system in the form of displays and announcement are provided in the saloon. It provides information about train status, speed, station details etc.
- Entertainment system- Entertainment system is proposed. Video screens are to be provided on each Executive class seat.
- PRM Facilities- Facilities required for the persons with reduced mobility is proposed. It includes special toilets and wheelchair area.

9.1.11 RAMS

All SilverLine Trains should meet RAMS criteria or at least its equivalent to assure high levels of service and safety. The concept of RAMS is to adopt a product approach to achieve passenger satisfaction. A management cycle based on application, observation and improvement of RS is repeatedly implemented in a process which can change the design process and maintenance system of RS.

RAMS of a component can only be achieved with thorough design and after extensive post-assembly testing. Forecasting RAMS of RS at the pre-operation stage depends on the RAMS of subsystems and their system trees. Testing prior to beginning operations should obviously be as thorough as possible in order to ensure RAMS is at an acceptable level. For stable operation, reliability and availability should be increased to the required level. Redundancy should be planned for the total train system, especially in the case of parts which are difficult to have redundancy such as mechanical components like bogies, doors, etc, the latter should be reliable enough not to affect operations.

9.1.11.1 Reliability

The SilverLine Rolling Stock shall be designed and constructed in such way as to guarantee a high degree of reliability in order to provide proper operating service.

Main standards used as a guideline for RAMS are EN 50126 IEC 61709/IEC62278 and for electronics IEC 61709. The reliability describes the aptitudes of the Rolling Stock to fulfil its functions during a certain time period. The design shall guarantee that faults in the circuit will not lead to operation dangers or harm to passengers and crew. Fault affecting the normal operation can be identified immediately. Fail safe principle shall be adopted in the design.

9.1.11.2 Reliability Indicators

Main performance indicators to measure the reliability are listed below:

- MTBF - Mean Time Between Failures - this is used to measure the reliability of the equipment;
- MTTR - Mean Time To Repair - this is used as a criteria in the specifications of an item to be procured. It is also used to measure the performance of maintenance personnel;
- MTBSAF - Mean Time Between Service Affecting Failures – Service affecting failures must be ideally zero; if they do happen then each occurrence needs to be carefully documented and preventive action taken to ensure such an occurrence never happens again in the future. Again, this is a key measure of reliability;

- MTBM - Mean Time Between Maintenance - this is again used as a criterion in deciding the equipment to be procured. Those offering the largest MTBM are obviously the best suited technically. This measure is also associated with system availability as well as reliability; it provides a good indication about the effectiveness of the maintenance undertaken and how much reactive maintenance is being incurred.

9.1.11.3 Failure Definitions

The failures will be classified in 4 category levels:

- **Relevant Failure**: A relevant failure of an item is an independent failure which results in a loss of function. These types of failures happened when an equipment or sub-system while operating within its design and environmental specification limits. These failures may lead to corrective maintenance after completing the intended service or doing an immediate withdrawal from service.
- **Non-Relevant Failure**: Any failure of an item not included in the definition of relevant failures.
- **Service Affecting Failure**: Any relevant failure or combination of relevant failures during revenue service operations, simulated revenue operations, or during pre-departure equipment status checkouts test to determine availability for revenue service.
- **Pattern Failure**: Repeated occurrence of three or more relevant failures of the same replaceable part, item or equipment in same manner in identical or equivalent applications when they occur at a rate which is inconsistent with the predicted failure rate of the part item.

9.1.11.4 Reliability Targets

Measurement of Reliability is based on the **MDBSAF** concept (Mean Distance Between Service Affecting Failures) adapted for SilverLine operation.

The Mean Distance Between Service Affecting Failures (minimum objectives to be reached) is associated with Service Affecting Failures counted on every month.

The Design shall be capable of achieving maximum Mean Distance Between Service Affecting Failures while operating on the proposed SilverLine Corridor. During the detailed design, specific value of MDBSAF shall be defined.

In addition to this, the following cases also to be considered:

- No credible single point failure of the Unit's traction, power supply, braking or train control systems shall cause a Train to be unable to move without external assistance while the 25kV power supply is available.
- No credible single point failure on the Unit shall lead to a Vehicle having no ventilation.
- No credible single point failure on the Unit shall lead to a Vehicle have no public address.

9.1.11.5 Availability

The availability targets are set for the SilverLine commercial operation. The calculation of the availability rate is done each day by the following equation;

$$\text{Availability} = \frac{\text{Nb of forecasted trips} - \text{Nb of trips not achieved due to shortage of Rolling Stock}}{\text{Nb of forecasted trips}}$$

A vehicle is declared as "available" when it is suitable for operating service. The availability targets shall be minimum 95% for the SilverLine Trains.

9.1.11.6 Maintainability

The maintainability of the train reflects its ability to be restored to its operation specification level within a stated period and under specific maintenance conditions.

The aim is to reduce the costs and delays and to improve the availability of the Rolling Stock fleet.

Reaching maintainability targets will help reduce:

- The size of the Rolling Stock fleet,
- Maintenance time,
- Spare parts stocks,
- Maintenance staff,
- Tools,
- Workshop facilities.

Currently, time-based maintenance for preventive maintenance is mainstream. However, if health monitoring or checking of the train’s state is used extensively, proactive maintenance replaces preventive maintenance, which can be treated as an option during the project execution.

In the case of minor maintenance work such as cleaning and waste disposal in particular, RS and maintenance facilities should be designed to enable this kind of task to be carried out speedily to avoid operational delays.

In addition to Rolling Stock maintenance, track side detecting devices for checking the Rolling Stock parameters and Condition monitored maintenance aspects may be considered as an option during the project execution.

9.1.11.7 Preventive Maintenance Targets

For achieving lowest operation and maintenance costs, the vehicles shall be designed according to the following criteria:

- Design for a life cycle of at least 30 years,
- The daily visual inspections and function controls can be performed by the drivers in the stabling yard area.

9.1.11.8 Corrective Maintenance Targets

Corrective maintenance targets are calculated with the following criteria:

- MTTR: Mean Time To Repair,

MTTR only integrate time to repair the failed function or module on the vehicle which includes:

- Diagnostic time,
- Repair time to remove or replace the failed component or module,
- Time for test and bring into service,
- Number of operators for each of the stages.

9.1.12 Safety

Safety is defined as absence of all those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property, or withdraw the train from service.

Safety performance shall be assessed by the risk levels of individual hazards identified during the system assurance process.

The safety of the Rolling Stock aims to reduce to an acceptable level the probability of occurrence of catastrophic and critical events.

The levels mentioned in Table 9-16 shall be used to classify the severity of the consequences of the hazards. Consequences considered are consequences for people, system and environment:

Table 9-16:Hazard Levels

Severity level	Consequences for people or environment	Consequences for system
Catastrophic	One or several fatalities and / or major damage to the environment.	Destruction of the System
Critical	Single fatality and /or severe injury and/or significant damage to the environment.	Loss of train or of a major system

Severity level	Consequences for people or environment	Consequences for system
Marginal	Minor injury and/or significant threat to the environment	Severe system(s) damage
Insignificant	Possible minor injury	Minor system damage

The design of the Rolling Stock shall reduce the Risk level of each of the above categorized hazard levels. Principle such as- “As Low As Reasonably Practicable” may be used for apportioning the severity levels.

9.1.12.1 Safety System

The main functions of the Rolling Stock through which safety is achieved are listed below:

- Braking system
- Door system
- Passenger Alarm System
- Dead man system device
- Sound and lighting system
- Safety loops in control circuits
- Fire protection
- Ventilation System
- Communication system
- Bogie Stability
- Crash Worthiness
- Interior designs
- Hot axle and gearbox detection system

Appropriate Safety Integrity Levels (SIL) shall be defined during the detailed design for the safety functions.

9.1.13 Life Cycle Costing (LCC)

LCC is central to evaluating cost effectiveness. The LCC encompasses all costs: purchase, operation and maintenance, renovation, scrapping and recycling. Train capacity is also an important factor for evaluating cost effectiveness.

European countries normally estimate the lifespan of HSRS to be around 30 years. France and Germany estimate it at 30 years for example. Given that RS has such a long life, it requires mid-life renovation. In Japan, HSRS is assumed to have a life of about 15-20 years and is not subject to the same renovation.

LCC helps in selecting the most financial attractive alternative. It can be used for evaluating Rolling Stock as a whole or individual components also during detailed design. This helps in optimizing the maintenance schedule of Rolling Stock.

LCC is an effective tool which optimizes the cost of labour, material, capital over a life span, for which it is to be operational. It is important to account for discounting as well as inflation. In any LCC some approximations and assumptions are made that is why it is effective for comparison between two or more alternatives. It is important that any organization introducing. LCC should focus first on authentic data collection. The life cycle plan shall use IEC 60300 standards as a guideline.

9.1.14 Energy Efficient system

Energy efficient system shall be used in the Rolling Stock. The following measures are recommended for energy efficient operation of SilverLine.

- Light weight car body by using Aluminium based car body.
- VVVF Drives for Traction and Auxiliary converters
- Extensive use of regenerative braking- During the service braking, the regenerative braking shall be used to the maximum extent possible. It is used at speed as low as 5 kmph
- With modern controls, power factor is maintained almost to unity.
- Energy efficient Lights- Lights shall be of latest technology such as LED for energy efficient operation. The light level shall be controlled based on the ambient light level. Windows shall be provided to increase the use of natural lighting.
- Air Conditioning- Optimised control of the temperature inside the train shall be provided to reduce the energy consumption in the Air conditioning units. The air conditioning system shall monitor the passenger load and ambient conditions. Similarly, the car body and windows shall be designed to reduce the heat transmission.
- In the propulsion system high efficiency transformer and IGBT based inverters shall be used.
- The aerodynamic design shall ensure less resistance which can reduce the traction energy consumption.
- Energy efficient train running shall be implemented during the project execution with the advisory system.
- All auxiliary machines are load controlled and VVVF driven to the extent possible.
- Optimised and modulated compressor operation
- Flange lubricators to reduce the wheel rail resistances

9.1.15 RORO Trains

‘Roll on Roll off’ service known as RORO is the rail transportation method in which trucks are loaded on the railway wagons and transport it for longer distances. It is also known as piggyback ride given to road trucks on railway wagons.

RORO services are intended to reduce the fuel consumption and other tear and wear maintenance of trucks which in turn reduces the CO_2 emission. RORO reduces the environment pollution as well as the road accidents. It serves to burn less fuel due to change of technology of transportation, thus contributing less to pollution and warming of climate. Such a service is being operated for crossing of Alps range of mountains in Switzerland as well as crossing Amazon forest.

On date, Roll on-Roll off (RORO) services are plying on Konkan Railway in India more on economic considerations. Loaded trucks with gross weight up to 45 tons and maximum height up to 3400 mm, are given piggyback ride on rail wagons between Kolad and Surathkal. The distance between Kolad and Surathkal is 1010 KM. The maximum allowed speed of the RORO service in this section is 75 kmph.

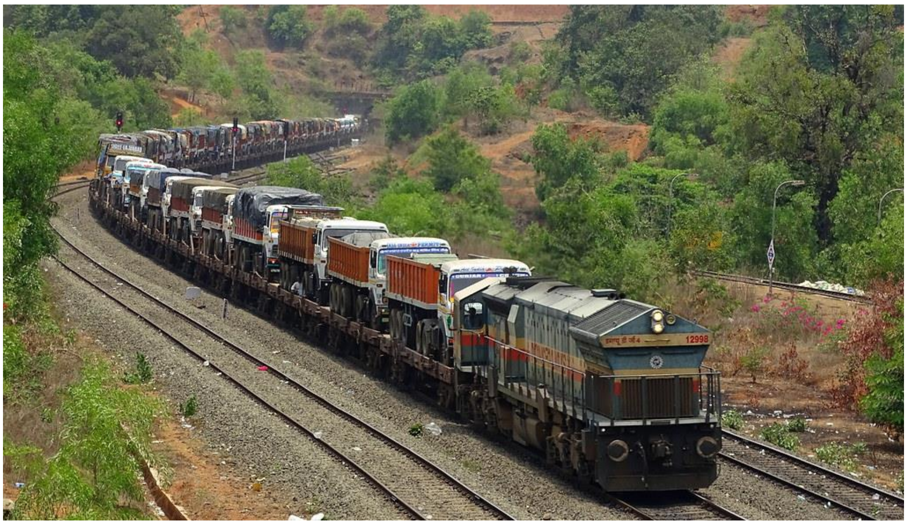


Figure 9-24: Konkan Railway RORO

Similar services are conducted on Europe and China successfully. Wagons loaded with truck are hauled by locomotive. The drivers are either accompany the truck or independent drivers at terminal stations shall drive the truck for loading and unloading of the truck from the train.

The proposed SilverLine corridor between Thiruvananthapuram and Kasaragod will utilize the alignment by providing RORO service on the same SilverLine track.

9.1.15.1 Rolling Stock for RORO

Electric Locomotive hauled train is proposed for the RORO services. Wagons are used to carry the trucks. Each wagon will carry one truck.

9.1.15.1.1 Locomotive

Heavy haul type electric locomotives are proposed to haul the RORO train. The maximum operational speed of the train is 120 kmph on the same SilverLine track. The locomotive shall have maximum axle load of 22.5 Ton. The car body of locomotive shall be made of structural steel. The locomotive shall be both directions driving type. Latest technologies shall be incorporated in the Locomotive design and manufacturing. VVVF controlled induction motors are used for the propulsion system. Disc/tread type brake system with adhesion control shall be used in the locomotive. The technical parameters of the Locomotive are listed in the Table 9-17.

Table 9-17: RORO Locomotive Features

Details	Requirements	Remarks
Gauge	Standard Gauge (1435 mm)	
Width	Maximum 3.2 m	
Length	Maximum 20 m	
Axle Load	22.5 Ton	
Maximum Operational Speed	120 kmph	
Propulsion System	VVVF controlled induction motors	
Brake System	Disc/tread type braking system	
Bogie	Co-Co or Bo-Bo Type	
Approximate power	5 MW per locomotive	
EB Distance in formation	1300 M	40 Wagons hauled by 2 Loco

9.1.15.1.2 Wagons

Standard gauge wagons are to be used to take the trucks on board. The wagon shall be of flat type with Bo-Bo bogie configuration. The maximum height of the wagon shall be limited to 1100 mm in order to limit the structure gauge dimensions. The wagons shall provide with flaps on end and side for loading of the trucks from both ends and sides of the wagon as per the requirement. There shall be locking mechanism for preventing the movement of the trucks during the train movement. There shall be earthing provision on the wagons to earth truck to wagon body.

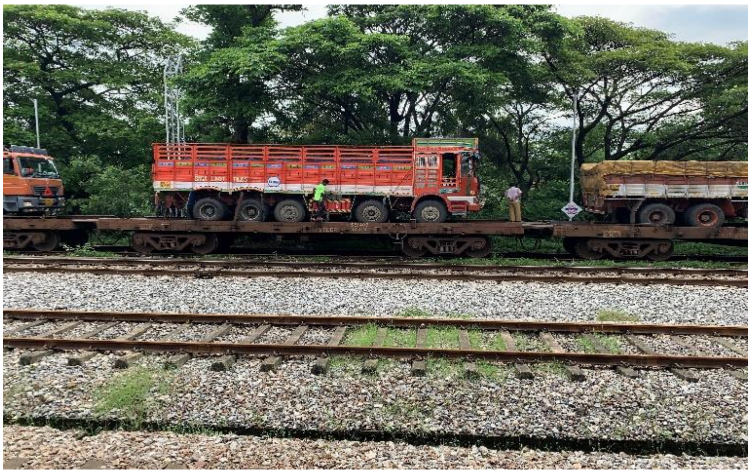


Figure 9-25: Wagons loaded with trucks

Sufficiently strong bridge plate shall be provided on ends of the wagon for movement of the truck from one wagon to the other.

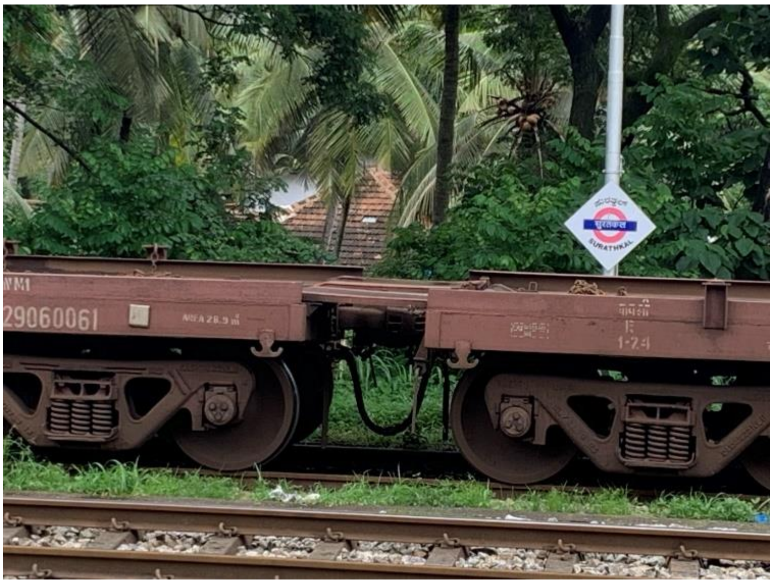


Figure 9-26: Bridge plate for cross movement

The technical parameters of the wagons are detailed in Table 9-18.

Table 9-18: RORO Wagon features

Details	Requirements	Remarks
Gauge	Standard Gauge (1435 mm)	
Width	Maximum 3.2 m	
Length	Maximum 15 m	
Floor Height	1100 mm	
Axle Load	22.5 Ton	The payload of wagon is expected to be 68 Ton
Maximum Operational Speed	120 kmph	
Brake System	Disc/tread type braking system	
Bogie	Bo-Bo Type	
Tare Weight of Wagon	Maximum 25 Tonne	

9.1.15.1.3 RORO Trains

The RORO trains are formed by two locomotives and 40 wagons coupled together. RORO train is equipped with signalling & train control system -ETCS level-2 with LTE. Two locomotives are required for hauling the train in steep gradient (1 in 60) and to maintain 120 kmph. The two locomotives shall be operated in synchronous way during traction and braking. The traction is achieved by the motors provided on the axles of the locos. In Locomotive the braking shall be blended braking with predominant usage of regenerative braking and supplementary usage of pneumatic braking. In the wagons the braking shall be achieved using pneumatic brakes only. The brake rate shall be synchronised in the whole train by the brake control electronics. In the steep gradient, adhesion-controlled traction and braking shall be implemented. The configurations of the RORO train is proposed Figure 9-27.

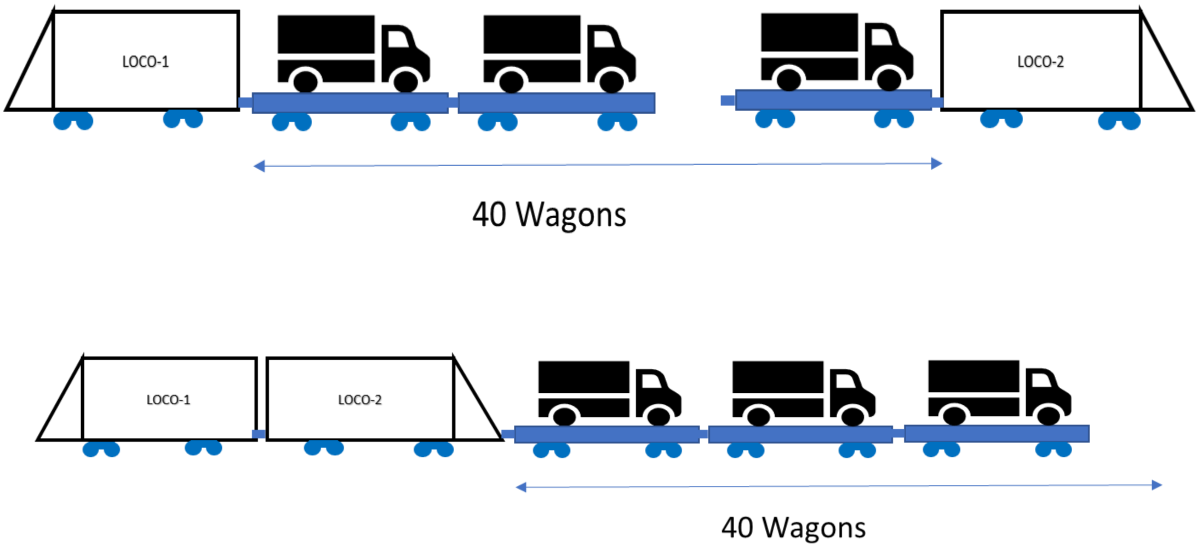


Figure 9-27: RORO train configurations

The trucks on the wagons shall be loaded either from the side of the wagons or from the end of the wagons (in Konkan railway, end loading is performed, however during discussions with K-Rail, it is proposed to use side loading in SilverLine even though there is no reference for side loading). For performing side and end loading of the truck to the wagons, the necessary infrastructures such as platforms and ramps are to be provided.

The height of the truck to be loaded on the wagon is limited to 3400 mm in order to respect the structure gauge dimensions. The maximum height of truck loaded on wagon from rail level shall be 4500 mm. The trucks shall be weighed, and height checking shall be done before loading to the wagon.

Table 9-19:RORO Train features

Details	Requirements	Remarks
Maximum Speed	Operational-120 kmph Design- 130 kmph	
Initial Acceleration	Not less than 0.2 m/sec^2	

Details	Requirements	Remarks
Average Deceleration	Not less than 0.6 m/sec^2	Emergency Brake Deceleration- Maximum 1.3 m/sec^2
Axle Load	22.5 Ton	
Train Length	Maximum 700 Meter	
Service Braking Distance	Less than 3000 M	
Emergency Braking Distance	Less than 1300 M	

9.2 DEPOT

9.2.1 Introduction

The purpose of a Rolling Stock depot can be put quite simply: it is to examine, maintain and overhaul Rolling Stock whilst providing suitable space for stabling stock. The core function of a depot is the provision of servicing, maintenance and stabling of Rolling Stock. At designated depots, they will also be designed to cater for heavy maintenance and overhaul work.

Rolling stock depots are critical for the maintenance team to maintain their fleet and ensure the reliability of their services. Each depot is unique, and its facilities are determined by the stock for which the depot provides maintenance and servicing.

A Rolling Stock maintenance support system has three levels: operational, light and heavy.

- The operational level of maintenance of the Rolling Stock might include lubrication and inspection of components, replacement of defective passenger saloon fluorescent tubes, or replenishing consumables such as sand or water at convenient times.
- The light maintenance work will be performed during time slots when no train service is required (that is, night-time) and will include minor overhaul work of short duration that does not remove Rolling Stock from operational availability.
- The heavy maintenance depot will undertake major overhaul work that makes the Rolling Stock unavailable for operational use for certain periods of time.

In order to have high reliability quality service level, it is important to provide a maintenance depot which ensures the following task:

- Rolling stock stabling,
- Rolling stock cleaning,
- Rolling stock daily security checks,

- Rolling stock maintenance operations,
- Fixed installation of the main line maintenance,
- Operation of the main line,
- Administration of the line.

Figure 9-28: Example of Depot

9.2.2 Depot Requirements

The vision for a depot is for a safe and fit-for-purpose collection of facilities and buildings that meets the immediate and future requirements of the depot facility operator. There are several facilities necessary for the maintenance depots. Also, various considerations need to be made and evaluated prior to detailed design work of the depot. These are general considerations and not a specification for the works and do not detail the civil works, railway system works or the M & E works which will be required to construct these facilities.

A depot should have:

- Contain the desired range of facilities and assets to meet the operational requirements of the maintenance assets that are appropriate for the range of rail vehicles that are to be serviced there.
- Be located to provide ease of access for maintenance and management personnel and contain modern welfare facilities that create a safe environment for efficient operation.
- Be designed to be adaptable for future needs.

Accordingly, the depot facilities mainly classified as given below:

- Workshops for the maintenance and storage of material and for the storage of tools and equipment required by employees assigned to the maintenance of each system or infrastructure,
- Storage space for the vehicles used for maintenance,
- Space for the maintenance of these vehicles.

Effective depots are designed to carry out specific tasks which are aligned with a train service operation plan. Depots carry out several activities, some examples of which are:

- Stabling.
- Waste tank emptying.
- Watering / tanking.
- Train wash.
- Sand box replenishment.
- Inspection and assessment (manual or automatic).
- Wheel re-profiling.
- Light maintenance activities.
- Heavy maintenance activities.
- Major overhauls.
- Bogie refurbishment.
- Interior cleaning.
- Underframe cleaning and bio-hazard management.
- Bespoke equipment maintenance (for example, HVAC systems).

The depot requirements are arrived based on the Rolling Stock maintenance plan. In addition to the maintenance plan, the operational requirement also decides the layout of the Depot. The safety and access criteria also play an important role in deciding the depot layout and equipment design. Despite that the equipment/facilities at depots and workshops are an important infrastructure to be used for 50 to 100 years, they shall be able to flexibly cope with changes and developments of Rolling Stock.

The SilverLine depot layout and the equipment provided in depot considers above mentioned aspects of depot design. The details of the facilities and the equipment required to maintain the SilverLine Rolling Stock is covered in this chapter.

9.2.3 Maintenance details of Rolling Stock

The details of the maintenance plan of the Rolling Stock is covered in the designated chapter. However, the summary of the maintenance plan of the Rolling Stock is shown for ready reference in Table 9-20.

Table 9-20: Maintenance Plan of SH RS

Level	Frequency
Level 0	Daily
Level 1	4000 KM or 48 Hours
Level 2	20,000 KM or 15 Days
Level 3	80,000 KM or 45 Days
Level 4	240,000 KM or 180 Days

Level	Frequency
Level 5	480,000 KM or 1 Year
Level 6	1,200,000 KM or 3 Years
Level 7	2,400,000 KM or 6 Years

Cleaning frequency of the Rolling Stock is shown in Table 9-21.

Table 9-21: Cleaning Frequency of SH RS

Cleaning Type	Frequency	Line Required
Daily Cleaning Exterior	Daily	Automatic Washing Plant
Daily Interior Cleaning	Daily	Stabling Bay Line (In Depot & Main Line)
Interior Light Cleaning	One Week	Stabling Bay Line
Heavy Interior and Exterior Cleaning	One Month	Heavy Cleaning Bay

The depot building and track facilities shall be planned to cater above maintenance intervals of the Rolling Stock. Similarly, the machinery and plants shall support the above maintenance intervals. The above details cover the preventive maintenance plans only. The depot facilities shall be capable of supporting the corrective maintenance of Rolling Stock.

9.2.4 Maintenance details of RORO Rolling Stock

The RORO train consists of two locomotives and 40 wagons. The maintenance schedule followed by Indian Railway is taken as a reference for determining the maintenance plan of Locomotives and Wagons.

The maintenance plan of RORO locomotive is provided in Table 9-22.

Table 9-22: Maintenance Plan of RORO Locomotive

Level	Frequency
Trip Inspection	45 Days
Service Inspection- IA	90 Days

Level	Frequency
Service Inspection- IB	180 Days
Service Inspection- IC	270 Days
Major Overhaul- MOH	18 Months
Intermediate Overhaul- IOH	6 Years
Periodic Overhaul- POH	12 Years

The maintenance plan of RORO wagon is provided in Table 9-23.

Table 9-23: Maintenance Plan of RORO Wagon

Level	Frequency
Major Overhaul- MOH	18 Months
Periodic Overhaul- POH	12 Years

The maintenance of the RORO Locomotives and the Wagons will be carried out in same facilities provided in Kollam and Kasaragod Depot. The Depot buildings and Machinery & plants are designed to cater the maintenance of two types of train viz. SilverLine trains and RORO trains.

9.2.5 Depot Location and Planning

9.2.5.1 Depot Location

Generally, the best place to position a new depot is on a site adjacent to the mainline which feeds into the terminal station where stock starts or ends a train diagram. Clearly this is never fully achievable, and compromises always have to be made. Sometimes suitable land is unavailable.

As per the feasibility report, it is proposed to have Depot at Thiruvananthapuram and Kasaragod. However, from the guidance from K-Rail and considering different factors such as land availability, land cost and operational flexibility, the proposed SilverLine Corridor will have two depots, One at Kollam and another one at Kasaragod. The depot at Kollam will have full-fledged depot facilities to cater daily inspection, preventive maintenance, major maintenances, overhauls, corrective maintenance and other activities such as cleaning, waste disposal etc. The depot at Kasaragod will have limited facilitates to cater daily inspection and some preventive inspections, cleaning, waste disposal etc. The details on the facilities provided on each depot is covered in subsequent sections.

As the Depot location is moved to Kollam from Thiruvananthapuram, additional facilities such as a dedicated loop line for train induction and withdrawal is to be provided at Kollam Station.

9.2.5.2 Depot Planning

The Rolling Stock depot caters the following:

- Workshop - to perform overhauling and major maintenance schedules involving lifting
- Inspections - Scheduled inspections
- Storage of trains - Stabling lines

For efficient traffic control and considering other factors, car depots are set up near corridor end stations ie. Kollam and Kasaragod. Inspection lines has been planned at both the terminal stations i.e. Kollam and Kasaragod and workshop lines has been planned at Kollam only. Based on the maintenance flow and size of the maintenance facilities, the workshop will be designed to carry out the demanded maintenance level.

The stabling of the train is managed in both depots as well as in mainline. For the operational flexibility the daily checking and preventive maintenance facilities are provided at both depots. The major maintenance facilities are provided in Kollam Depot.

The car depots are divided into two types: the ones that store trains and perform daily inspection, regular inspection, and unscheduled maintenance and the ones that have workshop facilities to perform bogie inspection and general inspection.

Table 9-24 shows the functions and roles of the various depots in this plan.

Table 9-24: Function and Inspection Classification

Station	Function		Inspection Classification			
	Depot	Workshop	General Inspection	Bogie Inspection	Daily and Regular inspection	Unscheduled maintenance
Kollam Depot and workshop	•	•	•	•	•	•
Kasaragod Depot	•		•	•	•	•

The train operation requires that Rolling Stock will appear in a platform on time, clean and watered and ready for full operational service for the first service of the day. The depot, in turn, will require Rolling Stock arriving in its reception sidings at planned times, ready for maintenance and cleaning. This can only be achieved by integrating the operation of the depot with that of the mainline network. The Kollam Depot is connected to mainline at Kollam station and ensures smooth induction and withdrawal of the train towards Thiruvananthapuram side and Kasaragod side. There are two track connections are provided for the redundancy purpose and it will help in train withdrawal and induction without disturbing the mainline operation. Similarly, the Kasaragod Depot connects to Kasaragod station terminal side. The Depot position along the corridor is shown in Figure 9-29.

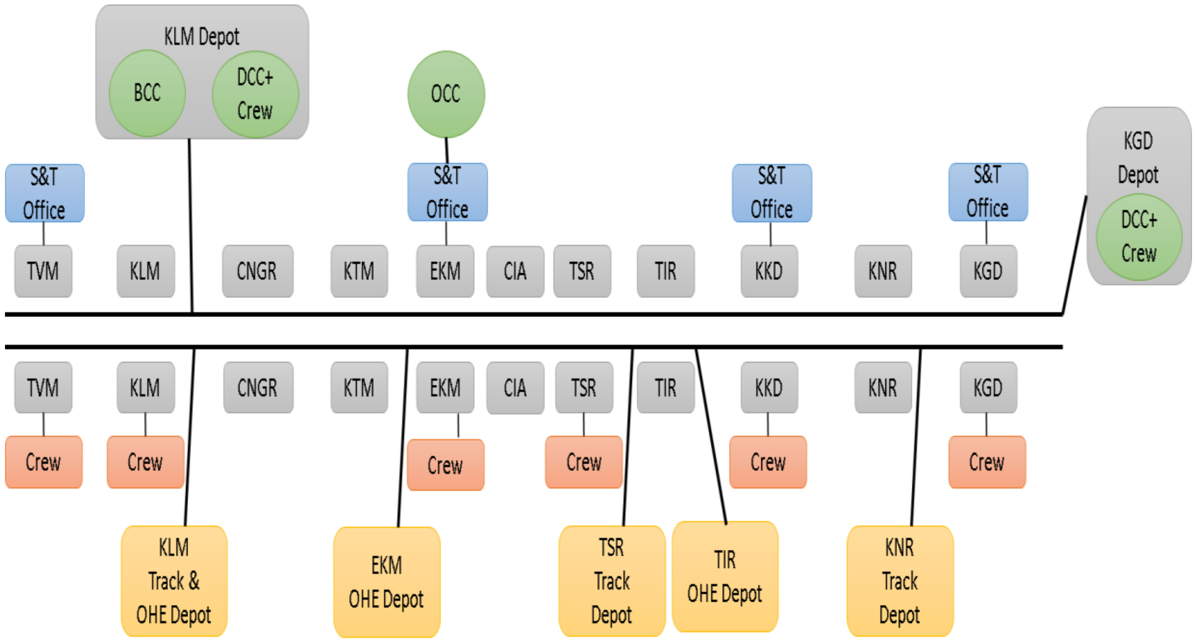


Figure 9-29: Depot Layout along the corridor

The land layout of both the Depots is shown in Figure 9-30.

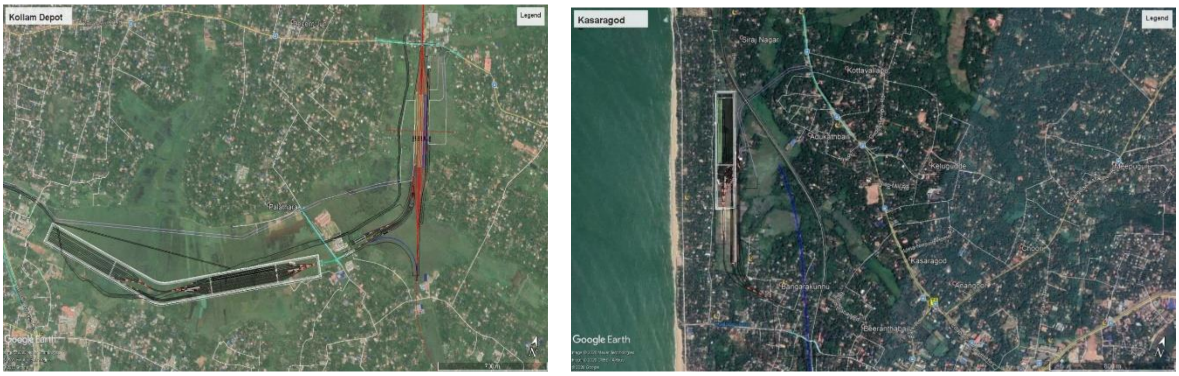


Figure 9-30: Land layout of Kollam and Kasaragod Depot

9.2.5.3 Depot Land and Layout

Since adequate land is available at Kollam and Kasaragod at grade Depots are planned in these locations with at grade connections to stations at Kollam and Kasaragod respectively. Ideally, the depot should have connections to the main line from both ends of the depot. Kollam Depot and Kasaragod Depot land are parallel to mainline, hence both side entry is not possible. Dual connection is proposed between and mainline and both Depots for operational flexibility.

All lines in the depot will be electrified to permit movement of the trains under their own power. Suitable isolation switches for the OHE will be provided to enable any particular section of the OHE to be isolated from the power supply, as and when needed.

The exact design and layout of the depot will depend on the maintenance requirement of the Rolling Stock finally chosen. Different manufacturers of Rolling Stock will have different maintenance philosophy and requirement of facilities. So, the final shape of the depot cannot be determined at this stage. However, the conceptual layout and facilities can be determined. Accordingly, the layouts of both Depots are shown in Figure 9-31 and Figure 9-32.

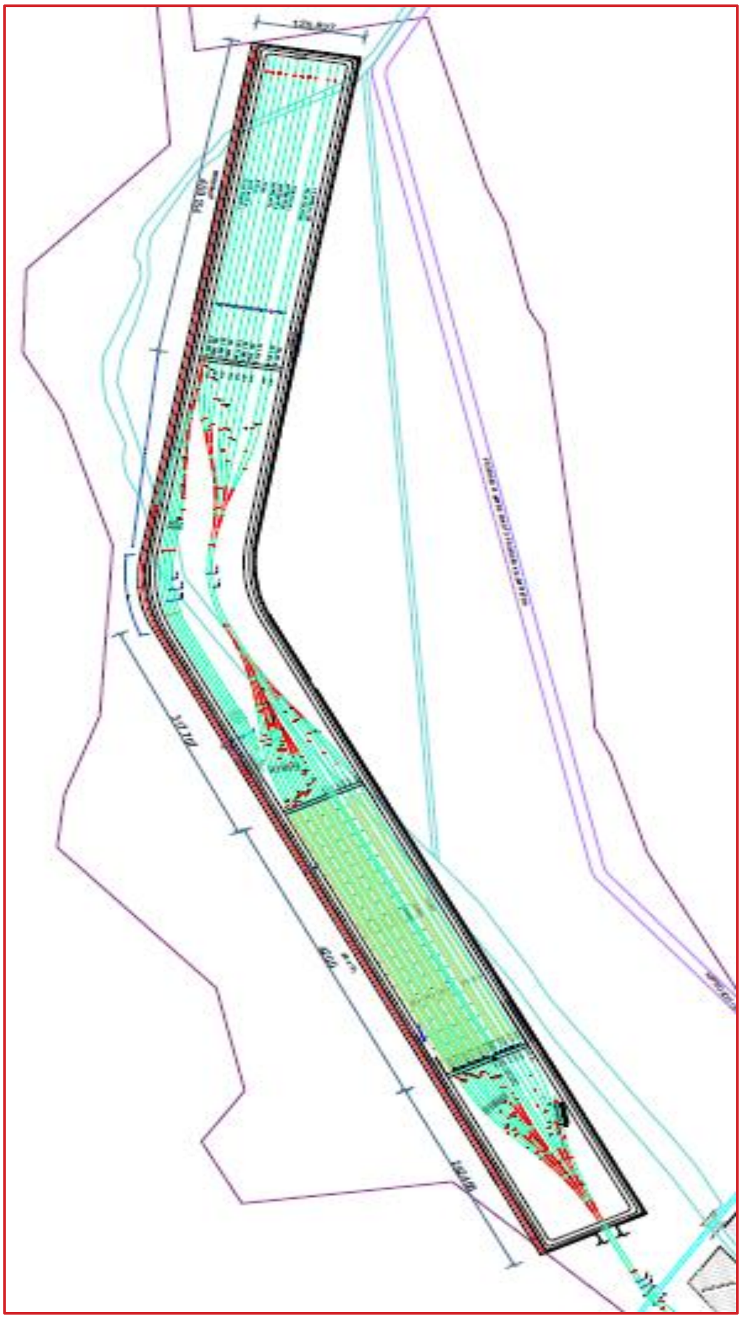


Figure 9-31: Layout of Kollam Depot

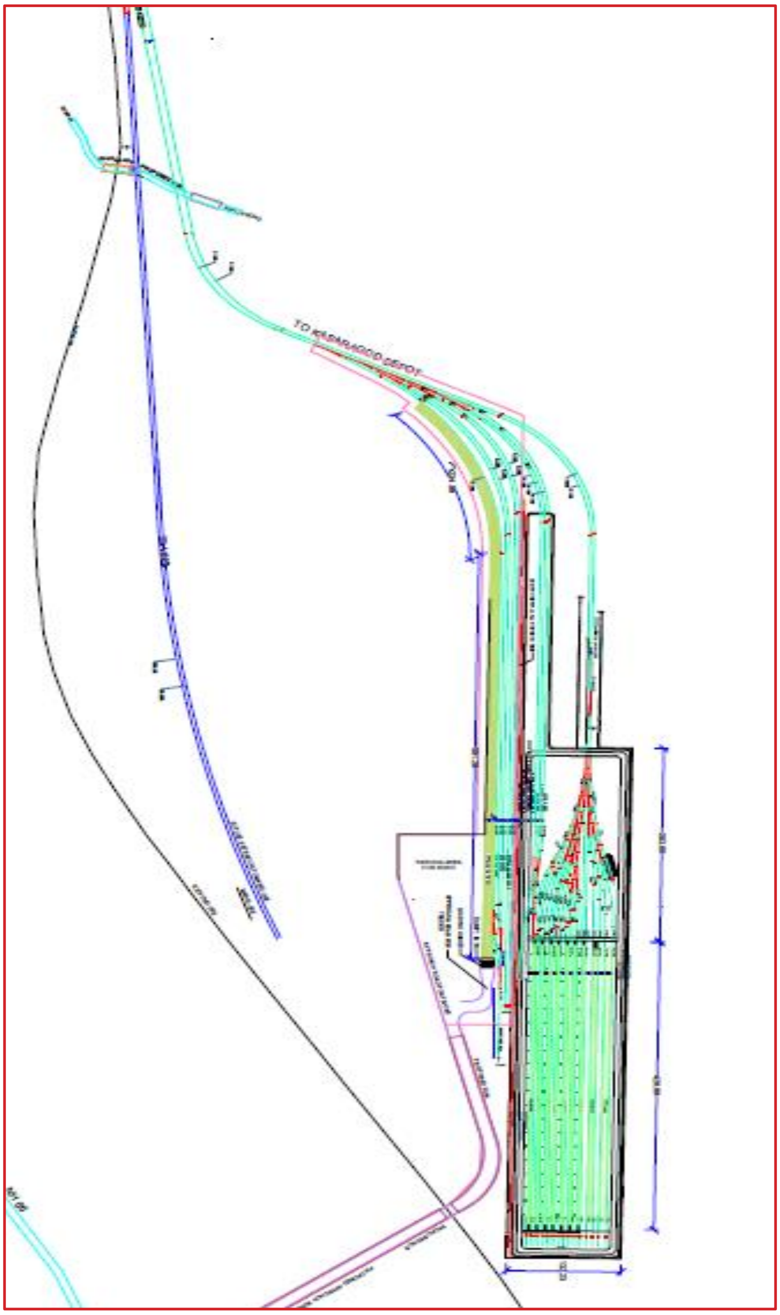


Figure 9-32: Layout of Kasaragod Depot

The approximate land requirement of Kollam Depot works out to be 34 Hectares and that of Kasaragod Depot works out to be 17 Hectares.

9.2.6 Depot Facility Details

Depot facilities are to be provided to conduct all type of maintenance activities of the Rolling Stock. The depot facilities are provided in both Kollam and Kasaragod Depot as per the maintenance requirements arising in each depot. The facilities in the depot shall be arranged in such a way that it will reduce the down time required for the maintenance of Rolling Stock, reduce the shunting movements required and make the Rolling Stock available on time for the operation. All the Depot facilities are provided considering train consisting 15 Car.

9.2.6.1 Rolling Stock Maintenance

The Rolling Stock maintenance schedule is mentioned above in this chapter. The operations study has determined the number of trains and the train composition that will be required for the SilverLine. By the year 2052-2053, there will be a total number of 46 Rolling Stock and 6 RORO trains, each that will be needed to carry the estimated passengers and freight. The stabling distribution will be 12 at Kollam Depot and 15 at Kasaragod Depot. Remaining trains are to be stabled in mainline and to be brought to Depot as per the maintenance requirement.

9.2.6.2 Depot Line Requirement

The maintenance requirement for the Rolling Stock will depend on the manufacturer. Each manufacturer of Rolling Stock will have his own recommended maintenance schedules and therefore the design of the facilities in the depot will depend on the Rolling Stock finally chosen. However, going by general international standards we can assume that the following maintenance line will be needed for various activities:

The maintenance bay lines required for conducting the maintenance of Rolling Stock is calculated based on the schedule of the proposed maintenance activities of SilverLine trains and RORO trains in 2052-2053 horizon year.

The Table 9-25 provides the line requirements for the SilverLine trains.

Table 9-25: Line Requirements of RS

Schedule	No. of examination per year	Working Days per year	Avl. Hrs per year	Hours req. per train	Total hr required	Line	No of Line Req.
Level 0	13800	300	2400	0.5	6900	SBL	45
Level 1	6900	300	2400	2	13800	IBL	5.8
Level 2	920	300	2400	4	3680	IBL	1.5
Level 3	276	300	2400	8	2208	IBL	0.9
Level 4	78.2	300	2400	12	938.4	IBL	0.4
Level 5	38	300	2400	28	1069	WBL	0.4
Level 6	13.8	300	2400	240	3312	WBL	1.4
Level 7	1.84	300	2400	480	883.2	WBL	0.4
Mid Life Refurbish	2.76	300	2400	720	1987.2	WBL	0.8
Corrective Maint.						WBL	1.0
Heavy Cleaning						HBL	1.0

The Table 9-26 provides the maintenance line requirements for the RORO trains.

Table 9-26: Line Requirements of RORO trains

Schedule	No examina tion per year	Working Days per year	Avl. Hrs per year	Hours req. per train	Total hr required	Line	No of Line Req.
Trip Inspection	600	300	2400	4	2400	SBL	7
IA	40	300	2400	4	160	IBL	0.02
IB	20	300	2400	6	120	IBL	0.01
IC	13.3	300	2400	8	106.667	IBL	0.01
MOH	6.7	300	2400	192	1280	WBL	0.13
IOH	1.6	300	2400	264	433.973	WBL	0.05
POH	0.8	300	2400	672	552.329	WBL	0.06
MOH-Wagon	133.3	300	2400	192	25600	WBL	1.1
POH-Wagon	16.4	300	2400	672	11046.6	WBL	0.5

Considering the maintenance line requirements of SilverLine trains and RORO trains, the following arrangement of maintenance lines are planned in two depots as shown in Table 9-27.

Table 9-27: Summary of Line Requirements

Depot	Inspection Bay Line (IBL)	Stabling Bay Line SHSR (SBL-400m)	Stabling Bay Line RORO (SBL-700m)	Workshop Bay Line (WBL)	Heavy Cleaning Bay Line (HBL)
Kollam Depot	5 Lines	12 Lines	2	6 Lines	1 Line
Kasaragod Depot	4 Lines	15 Lines		-	-

Balance stabling lines are to be provided on the main line as per operation flexibility. The main line stabling requirement is covered in the train operation plan.

The horizon wise line requirement is also listed in Table 9-28.

Table 9-28: Line Requirements Horizon year

Rolling Stock Track Lines Requirement															
Year	**TS Nos**	**SBL**	**Total Required**	**KLM Depot**	**KGQ Depot**	**TVM**	**KLM**	**CNGR**	**KTM**	**EKM**	**TSR**	**TIR**	**KKD**	**KNR**	**KGD**
2025-2026	SHSR-29*9 RORO-6	SBL Normal (400 M)	**28**	**12**	**6**	**2**				**2**	**2**		**2**	**2**	
		SBL RORO (700 M)	**7**	2		1	1			1	1				1
		IBL-400 M	**6**	**4**	**2**										
		WBL-400 M	**5**	5											
2029-2030	SHSR-33*9 RORO-6	SBL Normal (400 M)	**32**	12	7	2				3	4		2	2	
		SBL RORO (700 M)	**7**	2		1				1	1				1
		IBL-400 M	**7**	4	3										
		WBL-400 M	**5**	5											
2041-2042	SHSR-33*9 & 8*15 RORO-6	SBL Normal (400 M)	**40**	12	14	3				3	4		2	2	
		SBL RORO (700 M)	**7**	2		1				1	1				1
		IBL-400 M	**8**	4	4										
		WBL-400 M	**6**	6											
2052-2053	SHSR-33*9 & 13*15 RORO-6	SBL Normal (400 M)	**45**	12	15	4				4	5		3	2	
		SBL RORO (700 M)	**7**	2		1				1	1				1
		IBL-400 M	**9**	5	4										
		WBL-400 M	**6**	6											

9.2.6.3 Remote Stabling and Servicing

Considering the operational flexibility, reduced 'empty Rolling Stock mileage' and distance from ‘home’ depot are reasons that can help justify a case for remote servicing and stabling. As per the proposed layout of the Depot, 18 trains are to be stabled in the mainline which will much improve the operational flexibility and will avoid the empty Rolling Stock mileage.

In the mainline important stations such as Thiruvananthapuram, Ernakulam, Thrissur, Kozhikode & Kannur are proposed with stabling lines. However, the final stabling locations can be finalized in the detailed design keeping the stabling line requirement same. In remote stabling trains, daily inspection and light interior cleaning can be performed and necessary manpower and facilities shall be distributed.

Provision for water filling facility and waste collection facilities shall be provided in Thiruvananthapuram to avoid the empty train running and increase the availability of the trains for mainline operation.

9.2.6.4 Stabling Bay Lines

Stabling Bay Lines are provided for stabling the trains after completing the mainline operation. Daily inspection and light interior cleaning shall be performed in Stabling Bay Lines. In Kollam Depot 12 Stabling bay lines and in Kasaragod Depot 15 stabling lines are provided. 18 stabling bay lines are proposed in the mainline stations. Each stabling line will be of 400 m considering the 15 Car consist train with margin for cross movement, signalling, buffers etc. The stabling lines will be on ballasted track. There will be a concreted pathway of 1000 mm between the lines for the access of maintenance staff to the train. The stabling lines for RORO trains shall be of 700 M and 2 numbers are proposed in Kollam Depot. Remaining RORO trains are to be stabled in mainline.

The stabling area will be equipped with power supply distribution points for housekeeping. The stabling lighting will allow a safe and secure moving of the train driver and cleaning personals and the performance of the cleaning activities even if the train has been switched off. It shall ensure that no space is in the dark when the fleet is all stabled.

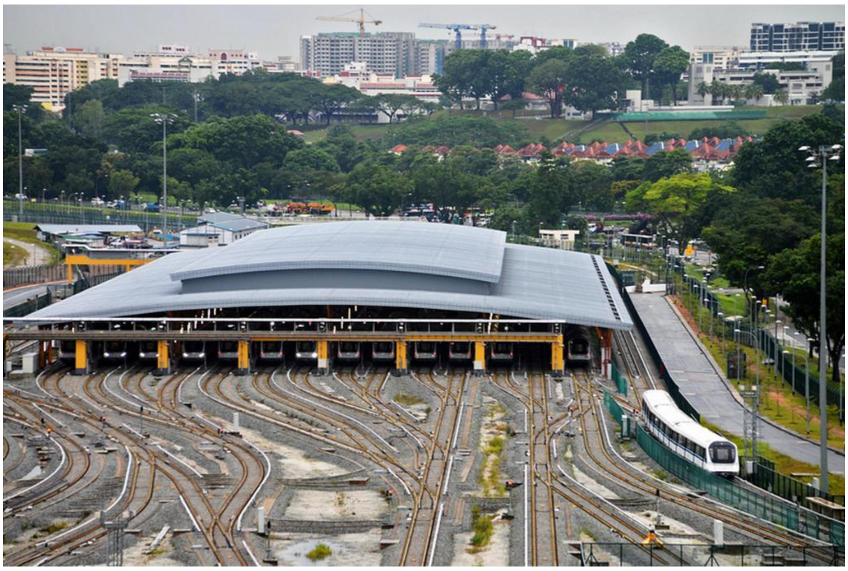


Figure 9-33: Stabling Bay Lines

9.2.6.5 Inspection Bay Lines

Inspection Bay Lines with raised track on pillars are provided in both Depot. The underframe of the train is accessible in the Inspection bay lines. The inspection bay line supports up to Level 4 maintenance of Rolling Stock. Inspection bay lines are covered shed having 400 m length. The floor of the shed will be depressed from the ground level and be concreted. The track will be ballastless, on raised pillars so that the roller bearings of the coaches are at sufficient height to enable a worker walking on the depressed floor to inspect the undercarriage comfortably.

There will be adequate lighting in the shed and under the platforms to permit working at night. Each bay will be served by one 5 tonne EOT cranes and one 1.5 tonne EOT cranes for each bay. There will also be sufficient compressed air and 220V, 415V power supply points along the track to permit use of small tools required for maintenance.

For accessing the roof, roof platforms are provided on two extreme Inspection Bay lines. The access to the roof shall be interlocked with the OHE power supply in the inspection bay lines. For the safety of the maintenance staff, the floor of the inspection bay line shall be marked with walkway indication and access indications. The pit in the inspection bay lines shall have sufficient lighting and water sewage facility. The inspection bay lines are provided with adequately sized office rooms, tool rooms, equipment rooms and storage rooms necessary for the maintenance of Rolling Stock. There are five IBL in Kollam Depot and four IBL in Kasaragod Depot.

Figure 9-34: Inspection Bay Lines

9.2.6.6 Workshop Bay Lines

Workshop bay lines are paved track meant to conduct the Level 5 and above scheduled maintenance of the Rolling Stock. The workshop bay lines are used for performing the overhaul and corrective maintenance of the Rolling Stock also. The workshop lines are provided with intermittent pits for accessing the underframe of the Rolling Stock. The workshop lines are covered shed with 400 m in length. The tracks are paved to ensure adequate space between adjacent lines for movement of material, machinery and components removed from the coaches.

There will be adequate lighting in the shed to permit working at night. There will also be sufficient compressed air and 220V, 415V power supply points along the track to permit use of small tools required for maintenance. Each bay will be served by one 15 tonne and one 3 tonnes EOT cranes.

In one of the workshop bay line pit jacks are provided for lifting of the Rolling Stock and Bogie removal. Two lines of the workshop bay line are occupied with bogie turn table for moving the bogie to bogie workshop. In addition to the pit jack, one set of mobile jacks are also provided for maintenance purpose. Portable platforms of height up to the coach floor level and roof level will be available to enable workers to attend to the coach.

Separate area is marked for the Bogie workshop and paint booth in the workshop area with dedicated track access.

The heavy repair bay will contain areas marked out on the shed floor, for repair and overhaul of heavy items like bogie frames, traction motors, transformers, compressors etc. These areas will be under crane. There will be rooms for supervisors' offices, material storage, testing consoles and component repair, along the side wall of the shed. Some of the important sections in the heavy repair bay will be:

- Body furnishing section
- Bogie section
- Wheels and roller bearing section
- Traction Motor section
- Transformer, Convertor / Invertor section

There are six workshop bay lines provided in Kollam Depot. There is no workshop facility is proposed at Kasaragod Depot.

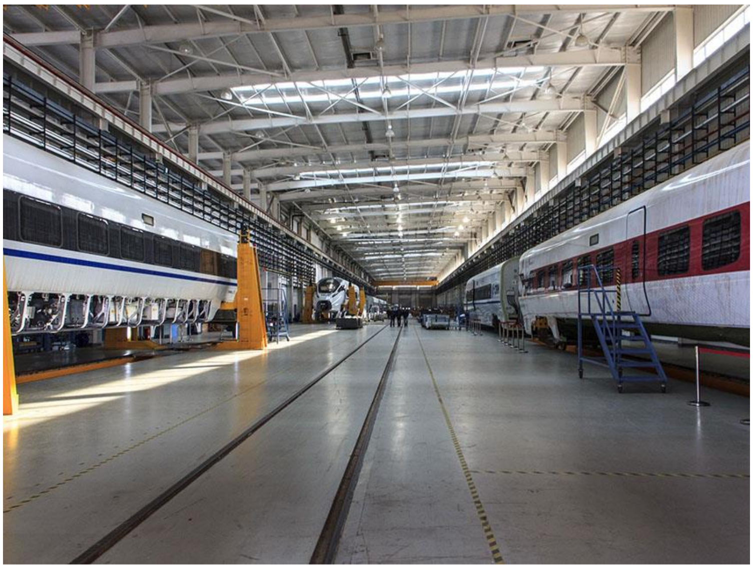


Figure 9-35: Workshop Bay Lines

9.2.6.7 Bogie Repair Shop

Dedicated space in the workshop area is earmarked for the Bogie repair shop. Bogie repair shop is used to do all kind of maintenance activities of Bogie. The Bogie will be removed using the lifting jacks and moved to the Bogie repair shop with the help of Bogie turn table.

An area of 215 m x 50 m is marked for Bogie repair shop. The Bogie repair shop mainly includes the following major equipment to handle the maintenance of Bogie

- Bogie Wash Plant
- Wheel Press Unit
- Bogie Test Stand
- Bear removing unit
- Ultrasonic testing unit

Bogie repair shop is proposed in Kollam depot only.

9.2.6.8 Automatic Wash Plant

Automatic wash plant is proposed on the approach track to depot. All the trains entering to the Depot after the revenue service will be washed before sending for stabling. The automatic wash plant is proposed to provide in Kollam and Kasaragod Depots. The washing of the tramways will take place when the tramways are running at low speed through the washing machine (3km/h).

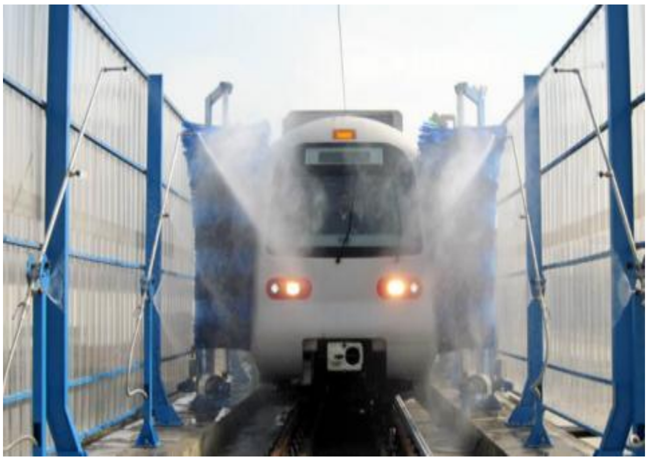


Figure 9-36: Automatic Wash Plant

9.2.6.9 Controlled Emission Centre

For the discharge and disposal of the toilet wastage inside the Rolling Stock, controlled emission centers are to be provided on approach track to Depot. The controlled emission centers will collect the toilet waste and dispose it properly. Associated treatment units shall be provided along with controlled emission centers. The CET plant shall be kept before the automatic washing plant in the entry track to the Depot. The CET plants are proposed at Kollam and Kasaragod Depots. Adequate lighting shall be provided in CET plant area for proper operation of the plant. The use of flexible discharge hoses provided on each side of the reception road to flush the CET system within the Rolling Stock units will provide a versatile facility.

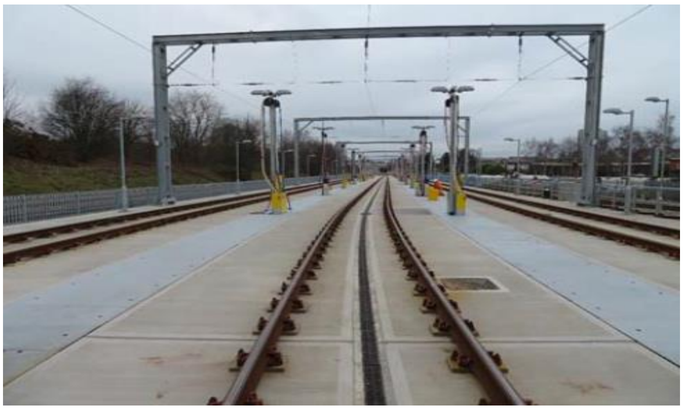


Figure 9-37: Controlled Emission Centre

9.2.6.10 Water Filling Station

Water filling station shall be provided on approach track to Depot. Water shall be filled in the trains before stabling. Water filling station is proposed in Kollam and Kasaragod Depots. Provision for providing Water filling station and CET plant in Thiruvananthapuram Station shall be kept. Water treatment plant and drainage facility shall be provided in the water filling station area.

9.2.6.11 Underfloor Wheel Lathe

Re-profiling of worn out or skidded wheels will be done by means of an underfloor wheel lathe. This enables the wheels to be turned in situ without having necessity to remove them from the coach. The wheel lathe will be housed in a separate shed which will be approximately 40 meters long and 15 meters wide. The whole train of 15 coaches will be sent for wheel turning. The covered shed must be sufficient to protect the wheel lathe and the staff working on the coach whose wheels are being attended. The rest of the train can be projecting out of the shed. The entire track for the wheel lathe shall be 425 m considering 15 car train consist.

A specific battery-operated hauling system will be provided for positioning the train on the wheel lathe. The under-floor wheel lathe will be sound proofed. It will be supplied with electricity and compressed air. A 1.5 tones overhead traveling crane is proposed in underfloor wheel lathe. Adequate lighting will be provided in the pits for carrying out the foreseen activities.

The underfloor wheel lathe is proposed in Kollam & Kasaragod Depot.

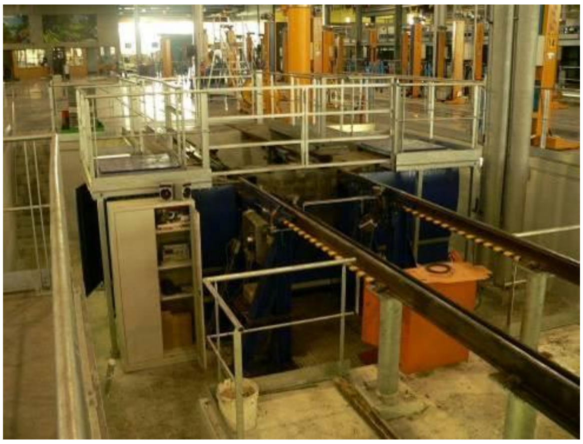


Figure 9-38: Underfloor Wheel Lathe

9.2.6.12 Painting Booth

There will be a modern painting booth with equipment for stripping of old paint, sand blasting, spray painting and drying. This will be a separate shed of 215m x 40m, provided with a suitable exhaust system to remove paint fumes. The tramway shall be positioned of on the painting cabin by using the hauling system of the wheel lathe. Painting booth is proposed in Kollam Depot only.

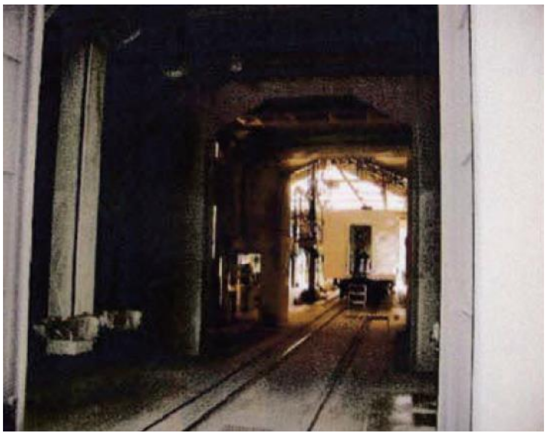


Figure 9-39: Painting Booth

9.2.6.13 Sand Filling Plant

In one of the inspection lines, the sand filling system shall be provided. Whenever the Rolling Stock sand level is reduced to the minimum level, it shall be brought to sand filling area for filling the sand. Sand Filling Plant is proposed in Kollam & Kasaragod Depots.

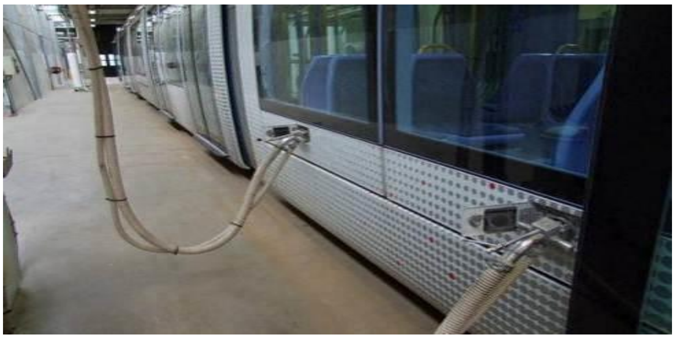


Figure 9-40: Sand Filling Plant

9.2.6.14 Heavy Cleaning Area

One dedicated track is allocated for heavy cleaning of the Rolling Stock with covered shed. The Rolling Stock shall be kept in raised track over pillars. In this plant exterior and underframe of the Rolling Stock is cleaned extensively. The Rolling Stock shall undergo heavy cleaning normally once in every month. The heavy cleaning shed shall have compressed air supply water supply. The area shall have pits with lights for accessing the underframe and sewage system. The shed shall be provided with roof access platform for cleaning the roof area and shall provide enough lighting for the carrying out the cleaning job. Heavy Cleaning area is proposed in Kollam Depot only.

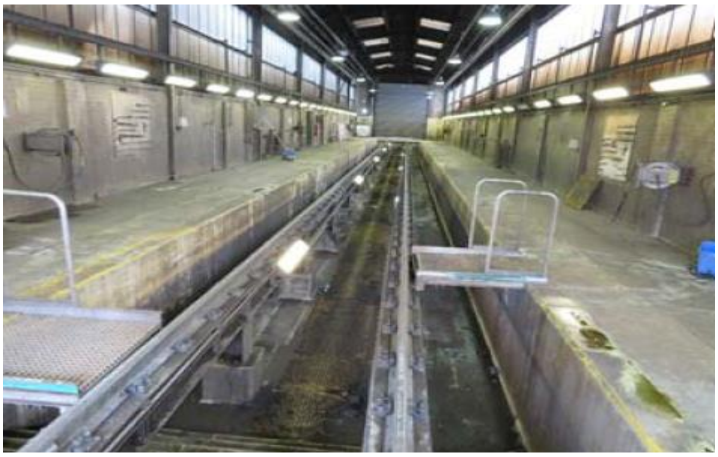


Figure 9-41: Heavy Cleaning Area

9.2.6.15 Test Track

An electrified track of approximately 1 km length will be provided to enable running tests of trains to be done after repairs. This track shall be at the outer boundary of the depot, removed from the working areas. Test track is proposed in Kollam and Kasaragod Depots.

9.2.6.16 Unloading Bay

A paved track is provided for delivering the Rolling Stock in the Depot. The Rolling Stock shall be brought using the trucks. The unloading bay is provided near to access road in the Depot. The paved track shall be of sufficient strength to cater the load of the cranes used to deliver the Rolling Stock. Approximately 15 m wide area is marked for delivering the Rolling Stock with a length of 425 m. Unloading Bay is proposed in Kollam Depot only.

9.2.6.17 Stores Building

A stores building will be provided in the depot to receive, store and issue material required for maintenance. It will also be used to collect scrap or defective items and transport them out of the depot. The stores building will be accessible by road. There will be a loading platform in front of the building where material from trucks can be loaded or unloaded. Specific scrap yard is provided for keeping the scrap materials.

The store will be divided into distinct storage areas for petroleum products, electrical components, mechanical components, general stores etc. Store issuers will have their office in the building and all material issued to or received from the workshop will be accounted for.

Store building and Scrap yard is provided in both Kollam and Kasaragod Depots. Since more maintenance activities are planned in Kollam Depot, 215m x 40m sized building is provided in Kollam Depot and a small-scale store having 80m x 80m sized store building is provided in Kasaragod Depot.

9.2.6.18 Office Buildings

The office buildings are distributed in the following locations

- Administrative Building in both Depots
- Workshop Bay Line in Kollam Depot
- Inspection Bay Line in both Depots

In addition to the above office building operational rooms are provided in following locations

- Operational Control Centre in Ernakulam Depot
- Depot Control Centre in both Depots

The Administrative Building will house the following:

- Offices for Technical, Financial, Administrative, Legal managers and staff
- Training Centre for operating and maintenance staff which will have classrooms, cut sections of important equipment, driving cab simulators etc
- Visitor’s lounge and Cafeteria
- Conference rooms

In both Depot 80m x 80m sized area is marked for administrative buildings.

In the inspection bay and workshop bay, there will be rooms to accommodate the offices of the shop floor supervisors as well as various repair sections, sub stores, tool rooms and test rooms. Some of the rooms like electronic equipment repair & test room, brake equipment repair & test room need to be dust proof and temperature controlled and so will need to be air-conditioned.

In addition to the office room facilities, the following facilities are ear marked in the Depot location

- Parking for two-wheeler and four-wheeler in both Depots
- Canteen for staffs in both Depots
- Access road in Depot connection all important locations of the Depot.
- Pedestrian foot paths.
- Security Building and Entrance facilities in both Depots

All of the offices and rooms will be equipped with electrical outlets, telephone connections and connection to LAN.

9.2.6.19 Water Supply and Treatment System

There will be in-house facilities for water supply for the entire depot. Sewerage, storm water drainage will be designed in the depot for catering to all the needs of the depot. Three separate networks will be provided: drinkable water, firefighting water and irrigation water for the landscaping. As the water consumption will be high in the washing plant, the washing machine will allow recycling the washing water. The wastewater will be treated according to regulations.

Specific treatment plants are provided for recycling the water and for treating the waste products of the maintenance activities.

9.2.6.20 Compressed Air Supply

Compressed air networks shall be provided in the workshop building and along the inspection stand located in the inspection bay and in Underfloor wheel lathe. In the compressor room an air treatment apparatus with a dryer and de-oiler will be installed along side, with a buffer tank equipped with an automatic electro-valve purging device.

The location of compressor is marked in the Depot substation area in both Depots.

9.2.6.21 Train Rescue facility

There is also a need to have an Accident Relief Train with Train Rescue equipment in both Depots for rescuing the train in case of derailment or accidents. It will have hydraulic re-railing equipment, lifting jacks, gas and hydraulic cutters, lighting equipment, DG sets.

9.2.6.22 Depot Substation

In both Depots, an auxiliary substation is planned to cater the loads of the Depot facilities and Machineries. In addition, there will be backup power supply through DG sets to keep general lighting, safety devices and inspection lines equipment, so that in case of power supply failure, light repair work can still go on and trains will not be affected.

9.2.7 Summary of Depot facilities

The summary and distribution of the Depot facilities are listed in Table 9-29.

Table 9-29: Summary of Depot Facilities

SL No	Depot Facility	Kollam	Kasaragod
1	SBL	Yes-12 Lines	Yes-15 Lines
2	IBL	Yes-5 Lines	Yes-4 Lines
3	Workshop	Yes-6 Lines	No
4	Bogie Repair Shop	Yes	No
5	Underfloor Wheel Lathe	Yes	Yes
6	Painting Booth	Yes	No
7	Unloading Bay	Yes	No
8	Heavy cleaning shed	Yes	No
9	Test Track	Yes	Yes
10	Controlled Emission Centre	Yes	Yes
11	Water filling Station	Yes	Yes
12	Automatic Wash Plant	Yes	Yes
13	Sanding Plant	Yes	Yes
14	Office Buildings	Yes	Yes
15	Store Department	Yes	Yes
16	Rescue Building	Yes	Yes
17	Water Pump & Tank	Yes	Yes
18	DCC	Yes	Yes
19	Depot Substation	Yes	Yes
20	Parking	Yes	Yes
21	Canteen	Yes	Yes
22	BCC	Yes	No
23	Treatment Room	Yes	Yes

SL No	Depot Facility	Kollam	Kasaragod
24	Training School	Yes	No
25	Simulator Room	Yes	No
26	Security Building	Yes	Yes
27	Scrap yard	Yes	Yes
28	RORO Loco & Wagon maintenance centre	Yes	No
29	Access Road	Yes	Yes
30	Welding Facilities	Yes	No
31	Fire Safety arrangements	Yes	Yes

9.2.8 Depot Machinery & Plants

The list of different major machinery and plants to be used in both Depots is listed in Table 9-30.

Table 9-30: List of Depot M&P

Depot M&P	Kollam	Kasaragod	Location in Depot
Automatic Wash Plant	1	1	Washing Apron
Pit Wheel Lathe	1	1	Underfloor Wheel Lathe
RRM for Wheel Lathe	1	1	Underfloor Wheel Lathe
Pit Jacks	1	0	Workshop Bay Line
Mobile jacks	1	0	Workshop Bay Line
Water Filling Station	1	1	Water Filling Apron
CET Plant	1	1	Waste Management Apron
Sanding Machine	1	0	Inspection Bay Line
Treatment Plants	1	1	Treatment Plant Area
Rescue Vehicle	1	1	Rescue Building
Air Compressor	1	1	Depot Substation

Depot M&P	Kollam	Kasaragod	Location in Depot
Battery Shunting vehicle	2	2	Inspection Bay Line
Accident Relief Train & Shunting Loco	1	1	Rescue Building
Bogie Test Stand	1	0	Bogie Workshop
Wheel press	1	0	Bogie Workshop
Bogie Wash Plant	1	0	Bogie Workshop
Work Lift Platform	8	4	Workshop Bay Line & Inspection Bay Line
Bogie Turn table	2	0	Workshop Bay Line
Mobile Lifting Table	2	1	Workshop Bay Line & Inspection Bay Line
Truck	1	1	Inspection Bay Line
AC Filter Cleaning machine	1	1	Inspection Bay Line
TM Motor Cleaning Unit	1	0	Inspection Bay Line
EOTs- 15 T	4	0	Workshop Bay Line
EOTs- 5 T	4	3	Inspection Bay Line
EOTs- 3 T	4	0	Workshop Bay Line
EOTs-1.5 T	5	4	Inspection Bay Line & Underfloor Wheel lathe

9.2.9 Depot Operation

Depot operation play an important role in providing a reliable and available revenue service to passengers. The train shall be maintained and made ready for the revenue service on time as per the mainline operation. The details of the Depot operation in connection with main line operation is detailed in the Train Operation chapter.

Both the Depot shall be capable of performing the following normal mode of operation:

- Rolling Stock starts from the stabling bay lines or inspection bay lines and goes directly to the main line for operation.
- Rolling Stock come back from operation, pass through controlled emission centre, washing machine, water filling facility and stabling or maintenance bay.
- Periodic maintenance activities imply movement from and to stabling /

maintenance bay (Inspection bay and Workshop Bay).

Both the Depot shall be capable of performing following degraded mode of operation:

- In case of depot traction power supply failure, the main line traction power supply shall be able to provide traction power to the depot in order to continue depot operation.
- In case of failure of any one turnout, from the insertion/removal of the Rolling Stock from the Line shall not be impacted. Disturbance of workshop tracks is acceptable.
- Double end stabling is preferred to single end to facilitate Rolling Stock movement in case of Rolling Stock failure and for ease of operation.
- In case of failure or maintenance of controlled emission centre, water filling facility and automatic washing plant, it shall be possible to by-pass them.

In this section the basic requirements provided in the Depot for facilitating the operation is covered.

9.2.9.1 Operation Control Centre

Operation Control Centre (OCC) is planned to provide in Ernakulam. OCC will control and manage the mainline operation of the trains. OCC also plays an important role in the train induction to mainline from Depot and train withdrawal from mainline to Depot.

9.2.9.2 Depot Control Centre

Depot Control Centre (DCC) is planned to provide in both Depots. DCC will control and manage all the operation inside the Depot and DCC plays an important role in sending and receiving trains to mainline. Crew room will be provided in the DCC for the train operator reporting and completing the formalities for depot operation. The traction power inside the Depot is controlled either from DCC or from the OCC as per the detailed design.

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 10
POWER SUPPLY ARRANGEMENTS

10 POWER SUPPLY AND TRACTION

10.1 HISTORY OF ELECTRIFICATION SYSTEM FOR HIGH SPEED RAIL

The system which uses electrical power for traction system i.e. for Mainline Railway, High speed Rail, Metros, Trams, Trolleys, etc. is called electrical traction. The track electrification refers to the type of source supply system that is used while powering the electric locomotive systems. The electric traction needs a power supply that the trains can always access. It must be safe, economical and user-friendly. It can use either AC (alternating current) or DC (direct current).

Transmission of power is always along the track using an overhead wire or third rail laid close to the running rails. AC systems always use overhead wires, DC can use either an overhead wire or a third rail. Both systems require at least one collector attached to the train so it can always be in contact with the power. The return circuit is via the running rails back to the substation. The running rails are at earth potential and are connected to the substation.

Worldwide, 25kV AC electrification system is adopted for the Mainline and High-Speed Rail (HSR) services. DC electrification system is used for mainly metros, tramways, etc.

There are two types of 25 kV, AC electrification systems available for mainline railways and HSR;

- ✓ 25kV system
    - 25 kV without Booster Transformer (BT)
    - 25 kV with Booster Transformer (BT)
- ✓ 2x25 kV system with Auto Transformer (AT) feeding

10.2 AC TRACTION POWER SUPPLY SYSTEM USED FOR HSR

In worldwide, 25 kV AC supply is adopted for operating the HSR lines except for Germany (where the Supply system is in 15 kV 16 2/3 Hz). The 2x25 kV traction feeding system has been used for the operation of High-Speed Rail (HSR) of Japan, France, Taiwan, South Korea, China, Spain, Italy, and **India.** **Table 10-1** shows the feeding system adopted in major countries, where HSRs are in operational. All the countries except for Germany, 2x25 kV with Autotransformer type feeding (AT) system is used.

Table 10-1: Feeding system adopted in major countries

Name of Country	Section	Feeding Voltage (kV)	Frequency (Hz)	Feeding system	Overhead equipment (OCS)
Japan	Tokyo to Morioka	25	50	2x25 with AT	Compound catenary
Taiwan	Taipei to Zuoying	25	60	2x25 with AT	Compound catenary
South Korea	Seoul to Busan	25	60	2x25 with AT	Simple catenary
China	Beijing to Tianjin	25	50	2x25 with AT	Simple catenary
France	Paris to Boudercourt	25	50	2x25 with AT	Simple catenary
Germany	Koln to Rhein/Main	15	16.7	1x15kV	Simple catenary with stitch wire
Spain	Madrid to Lieda	25	50	2x25 with AT	Simple catenary with stitch wire
Italy	Rome to Napoli	25	50	2x25 with AT	Simple catenary

10.2.1 Traction Feeding System adopted in Japan

In Japan , the first high speed train travelled by using 25 kV with Booster transformer (BT) feeding system. To prevent large arc occurring at the booster transformer sections, the Japanese National Railways (JNR) has started a study of autotransformers (AT) feeding system. After several field trials and simulation studies, the world’s first 2x25 kV autotransformer (AT) type feeding system was adopted in Japan for the commercial operation of Sanyo Shinkansen line from Shin - Osaka to Okayama. Later, theTokaido Shinkansen line was converted into 2x25kV system. Presently, approximately 60% of AC electrified sections of JNR, have adopted 2x25 kV feeding system, which includes almost the entire Shinkansen HSL network. **Figure 10-1** shows the AT system provided in Japan for HSR.

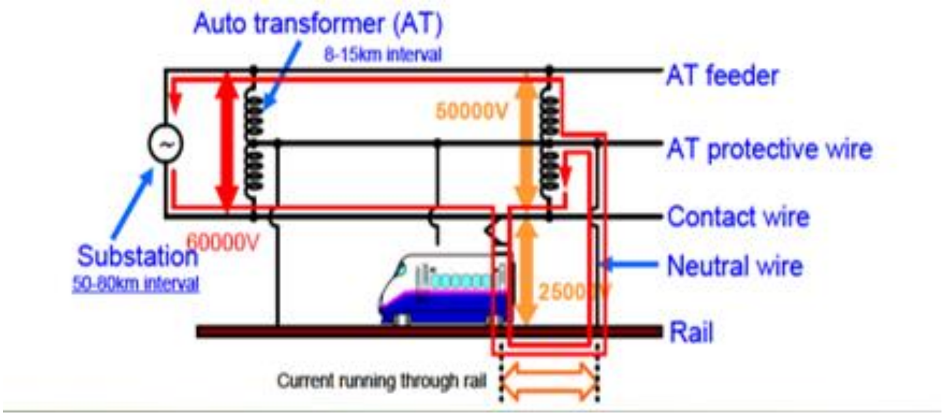


Figure 10-1: Japan AT System

10.2.2 Traction Feeding System adopted in France

The French National Railways (SNCF), has started the HSR operation by using 25kV feeding system without booster transformer, later they converted it to 2x25kV Autotransformer feeding system. They made several detailed studies on the 2x25 kV feeding system and adopted this system in their High-Speed TGV line between Paris and Lyon. The SNCF, based on the results on system studies and field operations, concluded that the AT feeding system is the most reliable and energy-saving power supply system for AC electrification. All HSR are consequently equipped with this system.

The Table 10-2 shows the history of the feeding system adopted for High - Speed Rail in Japan and France .

Table 10-2: History of the feeding system

Year	Country	Feeding System
1964	Japan (Tokaido)	1x25 kV with Booster Transformer
1972	Japan (Sannyo)	2x25 kV
1981	France (PSE)	1X25 kV without BT's (Partly 2x25 kV)
1989	France (Atlantique)	2x25 kV
1991	Japan (Tokaido)	Converted to 2x25 kV
2005	France (PSE)	Converted to 2x25 kV

10.2.3 Traction Feeding System adopted in Other Countries

The feeding system adopted for different countries Korea, China, Taiwan, Morocco, Russia, Saudi Arabia, UK, Spain, Italy, Malaysia, Thailand, California etc is 2x25kV Autotransformer (AT) type.

10.2.4 Traction Feeding System adopted in India

Indian Railways (IR) commenced revenue services by using the 25kV AC feeding system. Sometime in 1986, when the freight and passenger traffic in some of the electrified sections reached very high levels, IR conducted a special study of 2x25 kV system of electrification for adoption on high traffic non-electrified routes because the system was already well established by then and found eminently suitable for electrification of sections with heavy freight trains and/or high-speed passenger trains.

IR decided to implement a pilot project on 2 x 25 kV Autotransformer feeding system on Bina-Katni-Annupur-Bishrampur-Chirimiri section carrying heavy freight traffic, including coal, iron ore, finished steel, etc. The line is in operation for the last 20 years.

Indian Railway has implemented the 2x25 kV feeding system on its planned dedicated freight corridors eastern and western corridors of DFCC.

National High-Speed Rail Corporation Limited (NHSRCL) is implementing the project of a high-speed Rail corridor between Mumbai and Ahmedabad. The proposed traction feeding system for the HSR operation from Mumbai to Ahmadabad is AC ,50Hz, 2x25 kV Autotransformer type feeding system.

10.3 POWER SUPPLY ARRANGEMENT IN KERALA

The Kerala State Electricity Board Limited (KSEBL), is the successor entity of Kerala State Electricity Board which was constituted by the Government of Kerala under the Electricity (Supply) Act, 1948 for carrying out the business of Generation, Transmission, and Distribution of electricity in the state of Kerala.

The transmission network, the backbone of any power system enables the transfer of bulk power from the generating stations to the load canters. Over the years the intrastate transmission infrastructure in Kerala has grown substantially with the addition of more and more EHT substations and lines.

The transmission sector of KSEB Ltd is geographically divided into two zones - the North zone headquartered at Kozhikode and the South Zone headquartered at Thiruvananthapuram. Each zone is headed by a Chief Engineer. In addition to the above, the System Operations wing which performs the real-time management of Kerala Power System also comes under the Transmission SBU. The system operating wing is headed by a Chief Engineer and is headquartered at Kalamassery. **Table 10-3** shows the abstract view of the transmission system in Kerala.

Table 10-3: An abstract view of the transmission system in Kerala

Sr No	Voltage	No. of Substation
1	400 kV	1
2	220 kV	22
3	110 kV	163
4	66 kV	76
5	33 kV	153

A meeting was conducted with Kerala Rail Development Corporation officials, Kerala State Electricity Board officials and SYSTRA officials on 05.04.2019 at the office of Director/ KSEBL, Vydyuthi Bhavanam, Thiruvananthapuram. In the meeting, K-Rail has explained the power requirement and energy consumption (Traction and Auxiliary system) during Semi High-Speed Rail (SilverLine) operation. KSEBL has assured the availability of grid power in the proposed corridor of SilverLine. Operation of SilverLine by using 100 percent of renewable power and various charges for obtaining renewable power were also discussed in the meeting.

Vide letter N.G.O. No.069/KRDCL/2017 dt 10.05.2019, communicated to KSEBL for the availability of renewable power during operation and various charges to be paid to KSEBL for the purchase of renewable power as per current policies. Vide letter No. KSEB/TRAC/CG/Miscellaneous/2019-20/292 Dated 14.08.2019, KSEBL has communicated their willingness for serving 100% solar power during operation and intimated the statutory charges to be paid by K-Rail for availing open access power.

The **Figure 10-2** shows the transmission network of Kerala.

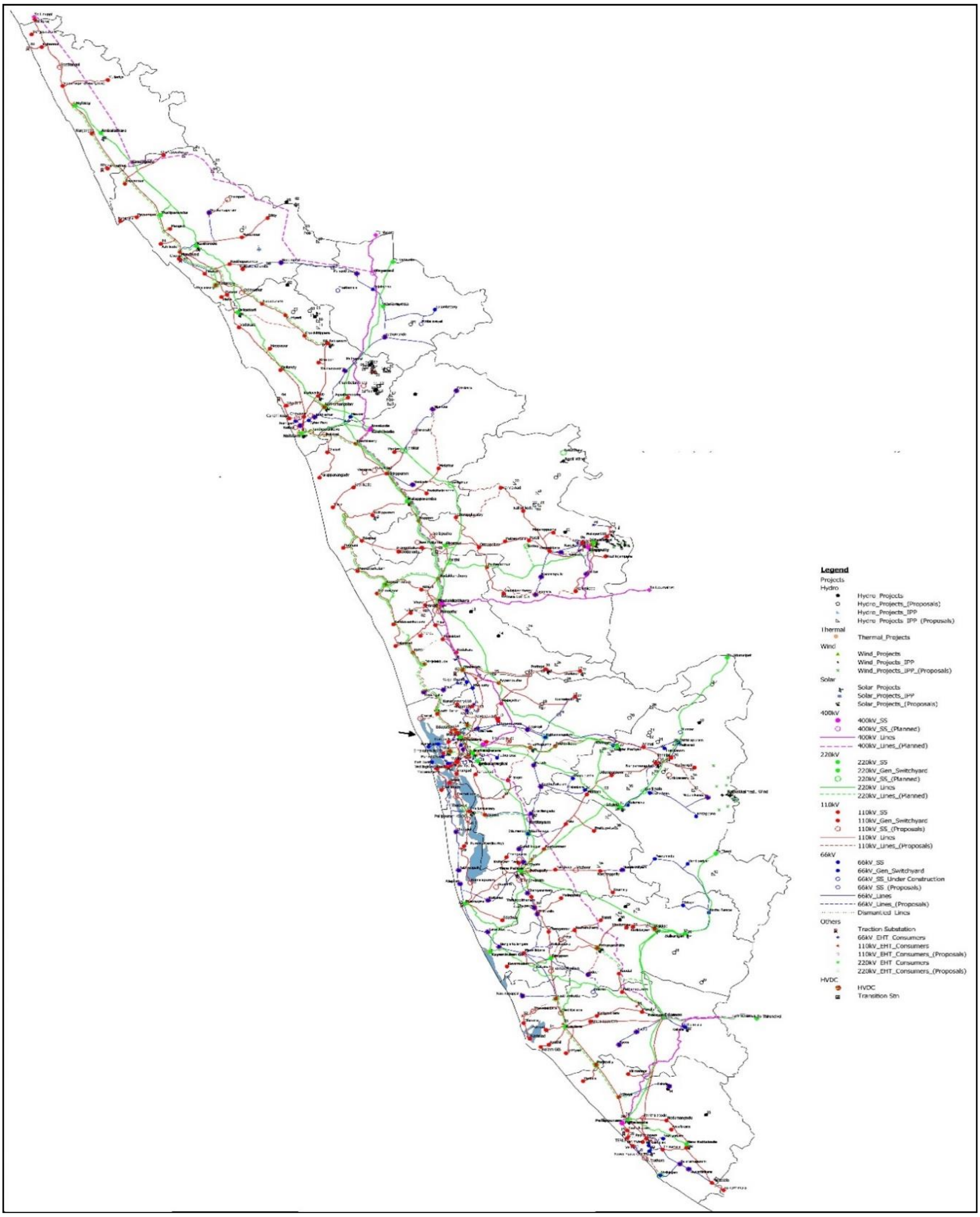


Figure 10-2: Transmission network of Kerala

10.4 HIGHLIGHTS OF POWER SUPPLY AND TRACTION SYSTEM FOR SILVERLINE

- In SilverLine corridor, the power supply and Overhead Contact System (OCS) are designed to cater the speed of 220kmph and extendable to 250kmph in future
- Power requirement and energy consumption for the years (2025-2026,2032-2033,2042-2043&2052-2053) is provided in Table 10-4.

Table 10-4 : Power demand and energy consumption

Year	Total Energy Consumption (Traction and auxiliary) in million unit	Power Demand (MVA)
2025-2026	279	104
2032-2033	321	119
2042-2043	427	158
2052-2053	497	184

- It is planned to use 100 percent of power from renewable sources for the operation of SilverLine corridor
- It is planned to provide the Solar panels on roof top of all station, depot and other administrative building, viaduct, compound wall fencing and intrastate/interstate
- A double circuit of 220/110kV supply to be availed from KSEBL for train operation (Traction) and 33/11kV supply to be availed from KSEBL for auxiliary systems (lighting, HVAC, escalator, elevator etc) in Stations and Depot
- There will be 8 Nos of Traction substations disseminated along the corridor to feed the traction supply and 13 Nos Auxiliary substations to feed the auxiliary supply to Stations and Depot
- It is planned to avail 11kV/ 415V or 415V supply from KSEBL for tunnel ventilation and lighting arrangements inside the tunnel
- The station, depot, administrative and other service buildings are to be designed based on the platinum rating standard of Indian Green Building Council (IGBC)
- The proposed traction power feeding system is AC, 50Hz, 2x25 kV Autotransformer (AT) type utilising a 25kV catenary and negative feeder(-25kV) together with autotransformers. The system voltage between overhead catenary and running rail is 25kV AC. The standard voltage of the system is

25kV. The highest permanent voltage is 27.5kV and the lowest permanent voltage is 19kV.

- The traction system will be as follows
    - There will be a spacing of 70 to 100 km between the Traction Substations (TSS)
    - The distance between Sectioning and paralleling post (SP) and traction substation (TSS) will be approximately 35 - 50 km and Sub sectioning and paralleling post (SSP)will be placed in between SP and TSS.
    - There will be autotransformer feeding at regular intervals
- Simple catenary type of Overhead Contact System (OCS) is proposed for the operation of SilverLine.
- **Table 10-5** shows the details of the proposed Overhead Contact System (OCS) adopted for SilverLine corridor

Table 10-5 : Proposed Overhead Contact System

Item	Main line	Depot and Siding
Type of Overhead Contact System (OCS)	Simple catenary	
Catenary wire	120mm^2, Cu alloy	65mm^2, Cadmium Cu
Contact wire	150mm^2, Cu alloy	107mm^2, Hard drawn Cu
Negative feeder	288 mm^2, Aluminium	

- SCADA system will be provided at Operation Control Centre (OCC) to monitor and control the traction supply
- Building Management System (BMS) will be provided at Operation Control Centre (OCC) and Station Control Room (SCR) to monitor and control the tunnel ventilation and auxiliary systems of stations and Depot.

10.5 POWER SUPPLY ARRANGEMENT FOR TRACTION SUBSTATIONS (TSS)

For the operation of SilverLine from Thiruvananthapuram to Kasaragod corridor, an EHV supply at the voltage level of 220/110kV need to be obtained from the Grid substation (GSS)/KSEBL to the various Traction Substations, distributed along the SilverLine corridor. The feasibility of getting the required power from the Grid substations of KSEBL was determined through discussions with the authorities of

KSEBL. They have ensured that the following Grid substations are available to supply the power for the operation of SilverLine. **Table 10-6** shows the availability of Grid Substations/KSEBL and Traction Substation/K-Rail in the corridor, from where power can be availed for train operation.

Table 10-6 : Proposed location of Grid substation

Sr No	Location of Grid Substation	Location of Traction Substation
1	220 kV Substation, Pothencode	Kazhakootam
2	220 kV Substation, Kundara	Kundara
3	220 kV Substation, Kottayam	Kottayam
4	110 kV Substation, Angamali	Angamali
5	220 kV Substation, Kunnamkulam	Kunnamkulam
6	110 kV Substation, Chevayur	Chevayur
7	110 kV Substation, Chova	Chova
8	220 kV Substation, Ambalathara	Ambalathara

GSS and TSS schematic arrangement of SilverLine corridor is provided in **Figure** 10-3

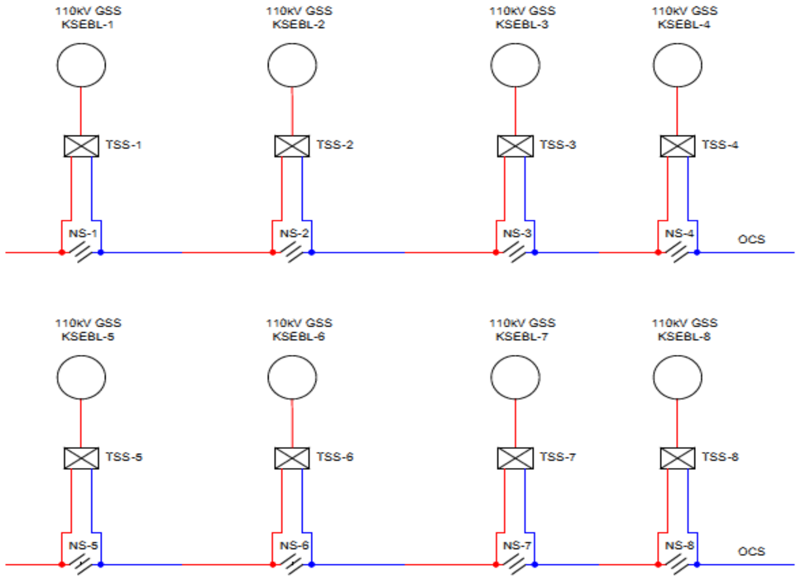


Figure 10-3: GSS and TSS schematic arrangement of SilverLine Corridor

The details of the proposed grid and Traction substation is provided in Table 10-7.

Table 10-7 : Distance between GSS and TSS

Sr No	Location of Grid Substation	No. of feeder bay	Length of UG cable/Transmission line from GSS to TSS
1	220 kV Substation, Pothencode	2 Nos of 110 kV feeder bay can be provided at 220kV Pothencode substation	The location of TSS is Kazhkootam and Feeder (from GSS to TSS) length is 4 km
2	220 kV Substation, Kundara	2 Nos of 110 kV feeder bay can be provided at 220kV Kundara substation	The location of TSS is at Kundara and Feeder (from GSS to TSS) length is 600m
3	220 kV Substation, Kottayam	2 Nos of 110 kV feeder bay can be provided at 220kV Kottayam substation	The location of TSS is at Kundara and Feeder (from GSS to TSS) length is 2.5 km
4	110 kV Substation, Angamali	2 Nos of 110 kV feeder bay can be provided at 110kV substation Angamali	The location of TSS is at Angamali and Feeder (from GSS to TSS) length is 2.5 km
5	220 kV Substation, Kunnamkulam	2 Nos of 110 kV feeder bay can be provided at 220kV substation Kunnamkulam	The location of TSS is at Kunnamkulam and Feeder (from GSS to TSS) length is 3km
6	110kV Substation, Chevayur	2 Nos of 110 kV feeder bay can be provided at 110kV substation Chevayur	The location of TSS is at Chevayur and Feeder (from GSS to TSS) length is 4.6 km
7	110kV Substation, Chova	2 Nos of 110 kV feeder bay can be provided at 110kV substation Chova	The location of TSS is at Chevayur and Feeder (from GSS to TSS) length is 75 metre
8	220 kV Substation, Ambalathara	2 Nos of 110 kV feeder bay can be provided at 220kV substation Ambalathara	The location of TSS is at Chevayur and Feeder (from GSS to TSS) length is 7km

10.6 POWER SUPPLY ARRANGEMENT FOR AUXILIARY SUBSTATIONS (STATIONS AND DEPOT)

A separate connection of 33kV/ 11kV needs to be availed from the KSEBL to cater to the auxiliary loads of Stations and Depot. Auxiliary sub-stations (ASS) are envisaged to be provided at each Station and Depot. Two dry type cast resin transformers (33/11kV to 0.415kV) of 500/630/1000/2500kVA capacity are proposed to be installed at the stations and Depot. Each ASS has 2Nos.of auxiliary transformers out of which, one transformer is working at a time and the second transformer acts as standby. A provision to be made available in 33/11 kV panel at stations to add the third transformer in the future to meet the increase in load (auxiliary and property developments). A Diesel Generator (DG) set shall be provided in each Stations and Depot as a backup arrangement. Solar photo-voltaic plants will be provided at the rooftop of Stations and Depot for availing the renewable power. Auxiliary Transformer (AT) supply shall also be availed for emergency loads in Stations. The location of 33kV/11kV supply to be obtained from KSEBL and location of auxiliary substation is provided in Table 10-8.

Table 10-8 : Proposed location of 33/11kV Supply

ASS No	Location of 33kV/11kV	Auxiliary Substation at Stations/Depot
1	110kV substation, Kazhakootam	Thiruvananthapuram
2	110kV Substation, Ayathil, Kollam	Kollam
3	33kV Substation, Chengannur	Chengannur
4	33kV Substation, Kottayam	Kottayam
5	33kV Substation, Ernakulam	Ernakulam
6	110kV substation, Angamali	CIAL - Cochin Airport
7	33kV Substation, Thrissur	Thrissur
8	33kV Substation, Kadagathundu, Tirur	Tirur
9	33kV Substation, Kozhikode	Kozhikode
10	33kV Substation, Kannur	Kannur
11	33kV Substation, Kasaragod	Kasaragod

ASS No	Location of 33kV/11kV	Auxiliary Substation at Stations/Depot
12	110kV Substation, Ayathil, Kollam	Kollam Depot
13	33kV Substation, Kasaragod	Kasaragod Depot

10.7 POWER SUPPLY ARRANGEMENT FOR TUNNELS

A separate connection of 11kV/ 415V needs to be availed from the KSEBL to cater the tunnel ventilation and lighting loads of SilverLine.

10.8 POWER SUPPLY ARRANGEMENT FOR SIGNALLING AND COMMUNICATION SYSTEM

To provide auxiliary supply to signalling equipment's in the wayside, a separate auxiliary transformer of single phase, 25kV / 230 V is to be provided and a 415/ 230V connection to be obtained from KSEBL, which acts as the redundant supply.

10.9 POWER REQUIREMENT (TRACTION AND AUXILIARY LOADS)

For any High-Speed Rail Transit System, power supply is essential for running the Train operation , Operation Control Centre, Station services (Lighting, Air-conditioning, Firefighting and alarm systems, Elevators, Escalator, Signalling and Telecommunications etc), Depot Services (Inspection shed, Workshop and Pit wheel lathe, etc), Tunnel ventilation and lighting and other maintenance infrastructure. The power requirements are determined by peak hour demands of power for traction and auxiliary applications.

The estimation of Traction and auxiliary power demand of SilverLine is calculated based on the following requirements:

1. Specific energy consumption of rolling stock
2. Regeneration of rolling stock
3. Station auxiliary load
4. Depot auxiliary load
5. Tunnel ventilation and lighting load

Table 10-9 to Table 10-14 show the power demand (Traction power and Auxiliary) and energy consumption projected for the year 2025-2026, 2032-2033, 2042-2043 and 2052-2053 of passenger and RORO service of SilverLine corridor.

Table 10-9 : Requirement and Consumption for Traction and Auxiliary

Year	Total Energy Consumption of Traction and auxiliary (Million Unit)	Power Demand (MVA)
2025-2026	279	104
2032-2033	321	119
2042-2043	427	158
2052-2053	497	184

Table 10-10 :Power demand and Energy consumption of Traction

Year	Energy Consumption (Million Unit)		Total Energy Consumption (Million Unit)	Power Demand (MVA)
	For Passenger Train	For RoRo Train		
2025-2026	201	62	263	84
2032-2033	241	62	303	98
2042-2043	345	62	407	136
2052-2053	413	62	475	160

Table 10-11 : Demand and Consumption of Auxiliary loads (Station, Depot, Tunnel)

Year	Total Energy Consumption (Million Unit)	Power Demand (MVA)
2025-2026	16	20
2032-2033	18	21
2042-2043	20	22
2052-2053	22	24

Table 10-12 : Power requirement and Energy consumption for Stations

Year	Power requirement for 11 Station (@ 0.5 MW/11 station)	Total auxiliary power requirement (MVA)	Operating hour per day	Diversity factor	Energy consumption Per day (kwh)	Energy consumption Per Year (Million unit)
2025-26	5.5	6	20	0.25	27500	10
2032-33	5.5	6	20	0.25	27500	10
2042-43	5.5	6	20	0.25	27500	10
2052-53	5.5	6	20	0.25	27500	10

Table 10-13 : Power requirement and Energy consumption of Depot

Year	Power requirement for 2 Depot (MW)	Total auxiliary power requirement (MVA)	Operating hour per day	Diversity factor	Energy consumption Per day (kwh)	Energy consumption Per Year (Million unit)
2025-2026	3	4	20	0.25	15000	5
2032-2033	4	5	20	0.25	20000	7
2042-2043	5	6	20	0.25	25000	9
2052-2053	6	8	20	0.25	30000	11

Table 10-14 : Power requirement and Energy consumption of Tunnel

Year	Power requirement of Total tunnels (MW)	Total auxiliary power requirement (MVA)	Energy consumption Per month (kwh)	Energy consumption Per Year (Million unit)
2025-2026	8.25	10	82500	1
2032-2033	8.25	10	82500	1
2042-2043	8.25	10	82500	1
2052-2053	8.25	10	82500	1

The requirement of PD load is not considered in estimation of auxiliary power calculation

10.10 POWER SUPPLY AND TRACTION SYSTEM

Traction electrification system is the combination of traction power supply system, Overhead Contact System (OCS) and associated Supervisory Control and Data Acquisition system (SCADA). The power supply system and Overhead Contact System (OCS) shall be designed to continue the train operation in case of disturbances. This can be achieved by extending power from the adjacent Traction substation (TSS) by closing the bridging circuit breaker of sectioning and paralleling post and installation of redundant equipment in substations. The power supply and OCS system are designed to cater to the speed of 220kmph and extendable to 250 kmph in future. **Figure** 10-4 represents the typical arrangement of Power supply and traction system for HSR.

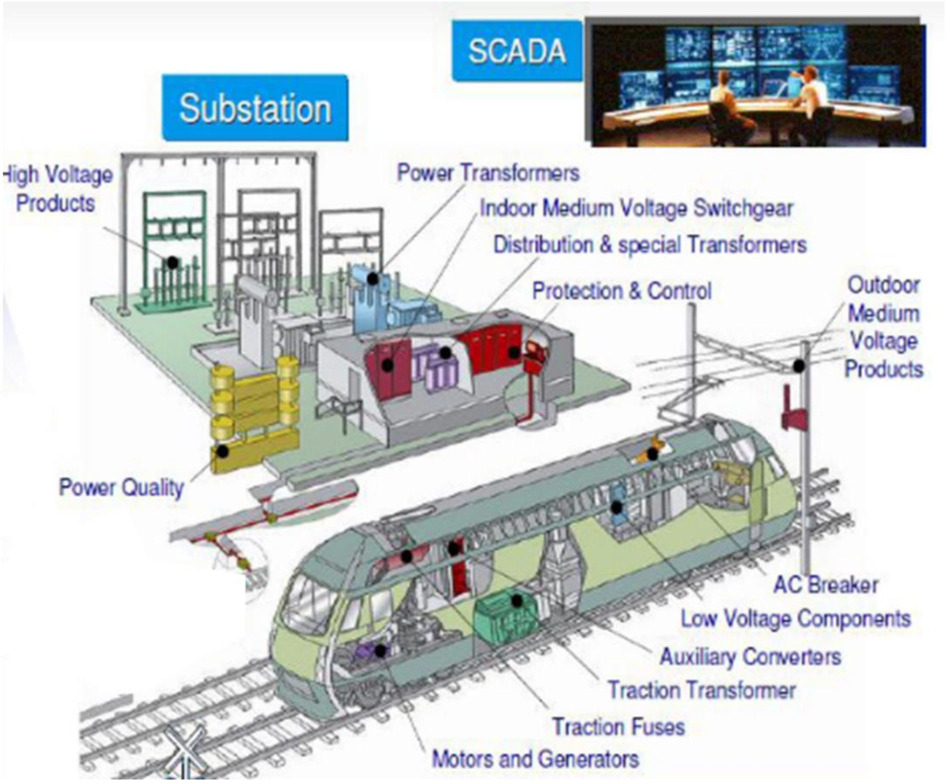


Figure 10-4: Typical Arrangement of Power supply and Traction system for HSR

The power supply system installations shall be designed in order to provide adequate power to the rolling stock for optimal operation and to cater the power requirement up to the year 2051 and this system shall support the maximum load current, the tractive effort and braking effort available/permissible at different speed and the train acceleration/deceleration/adhesion characteristics.

The power supply and Traction system shall have following subsystems

- Traction Substations
- Overhead Contact System (OCS)
- The disconnecting switches - OCS shall be electrically divided into sections (Sectioning and Paralleling Post - SP) and subsections (Sub sectioning and Paralleling post -SSP) for the disconnection of power supply.
- The neutral sections between two adjacent substations
- Traction return and earthing system
- Control and monitoring system

The general sectioning arrangement of traction feeding system of HSR is provided in **Figure 10-5**. It includes Traction substation, Overhead Contact System (OCS), Sectioning and Paralleling post (SP) and Sub sectioning and Paralleling Post (SSP) for sectioning.

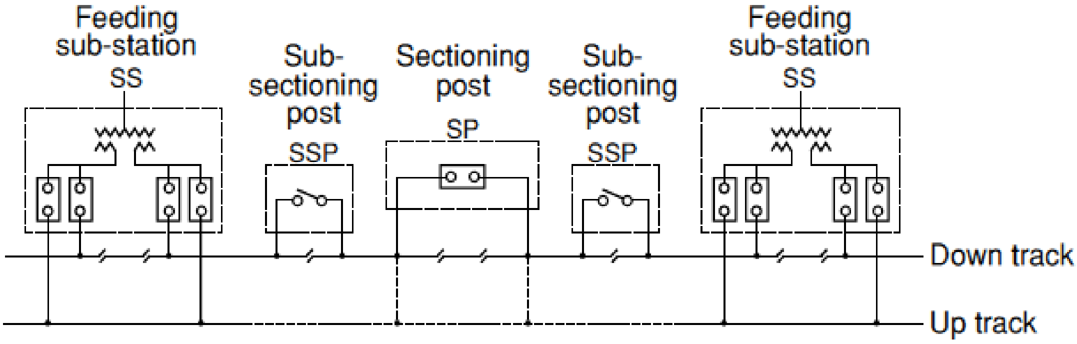


Figure 10-5: General sectioning of Power supply and Traction network of HSR

The general safety technical requirements of the electrical system for SilverLine are as follows:

- The power supply network shall be designed to ensure the safety of the passengers, staff, and the public under normal operating and fault conditions by the provision of suitable grounding and bonding arrangement
- All power supply equipment with an electrical potential difference to ground shall have adequate distance from public access and/or suitable shielding and warning sign to prevent accidental or unintentional contact by the general public or SilverLine staff;
- Power and control cables shall be fire retardant, low smoke and non-toxic;

- The earth resistance of the grounding system and the contact resistance of the bonding connection must be low enough to ensure that the permissible step or touch voltages whether under normal or fault conditions caused by earth current are not exceeded.

10.10.1 System Voltage

The system voltage of SilverLine shall conform to European standards EN 50163, Railway applications - supply voltage of Traction systems, IEC 60850 and EN 50388, Railway Applications - Power supply and Rolling stock. **Table 10-15** shows the voltage of the Overhead Contact System according to the standards.

Table 10-15 : Voltage of Overhead Contact System

Classification	Voltage
Nominal/standard voltage	25 kV
The highest permanent voltage	27.5 kV
The highest non-permanent voltage	29 kV
The lowest permanent voltage	19 kV
The lowest non-permanent voltage	17.5 kV

10.10.2 Traction Substation (TSS)

Traction substations are placed in the corridor of SilverLine to provide a traction power supply to the rolling stock. A 220/110kV incoming supply will be availed from the KSEBL grid. The 220/110kV supply will be stepped down to 50kV (2x25kV) for traction purpose at the TSS and the 50kV supply will be fed to the feeder and catenary wire. These substations are connected to the utility grid by three-phase, high-voltage feeder lines entering the high-voltage switchyards where primary power protection (lightning arresters, switchgear, circuit breakers, over/under voltage protection) is included. Since the power distribution network is an important part of system performance, each substation is functionally redundant. In each TSS, two traction transformers are available; one will feed the traction supply and the other acts as hot standby. The spacing between adjacent substations is normally between 70 and 100 km.

In case of any outage of one TSS, train services shall be maintained by extending the traction supply from adjacent TSSs. In case of total grid failure, all trains may come to a halt, but station lighting and other essential services can be catered by a stand by DG set, provided at Stations and Depot. The traction substation and re-configuration capabilities shall be such that in the event of a power loss to one of the incoming HV feeder line or temporary outage of one of the transformer, the remaining transformer of the TSS shall be able to supply power to the sections normally handled by the TSS. Both the power traction transformers shall be individually capable of supplying the full normal load of the substation.

The secondary phases of each transformer will be connected to the main and teaser buses through circuit breaker. The main and teaser buses in turn will be connected to the catenary and negative feeder respectively through circuit breakers and motorised disconnect switches.

The following points shall be considered for the selection of Traction Substation

- Availability of Grid substation (GSS)/KSEBL in the nearby location of the alignment
- Norms for locating the Traction substations based on the capacity of Transformer, load and Voltage regulation
- Traction substations shall be approachable by road and preferably by railway for better connectivity by road and rail

For every successful traction system, certain general requirements shall be met

- The capability of starting and hauling a prescribed train over its specified routes while maintaining running times as scheduled in advance
- Satisfactory service life
- Satisfactory reliability, availability and maintainability
- Efficiency in the delivery and consumption of power
- Minimum environmental impact

At present, two types of Traction substations are used in HSR, railways and metros

1. Air-insulated Substation (Outdoor)
2. Gas Insulated Substation (Indoor)

The land requirement of conventional outdoor type substations is mentioned in Table 10-16.

Table 10-16 : Land area of Outdoor Substation, SP and SSP

Sr No	RSS/SP/SSP	Plot Size (mtr x mtr)	Area (Sq Mtr)
1	RSS (220 kV)	150 x 110	16500
2	RSS (110 kV)	140 x 75	10500
3	SP	55 x 30	1650
4	SSP	55 x 25	1375

The typical equipment arrangement of outdoor substations, where all the switch gears and transformers are placed outside is shown in **Figure 10-6**

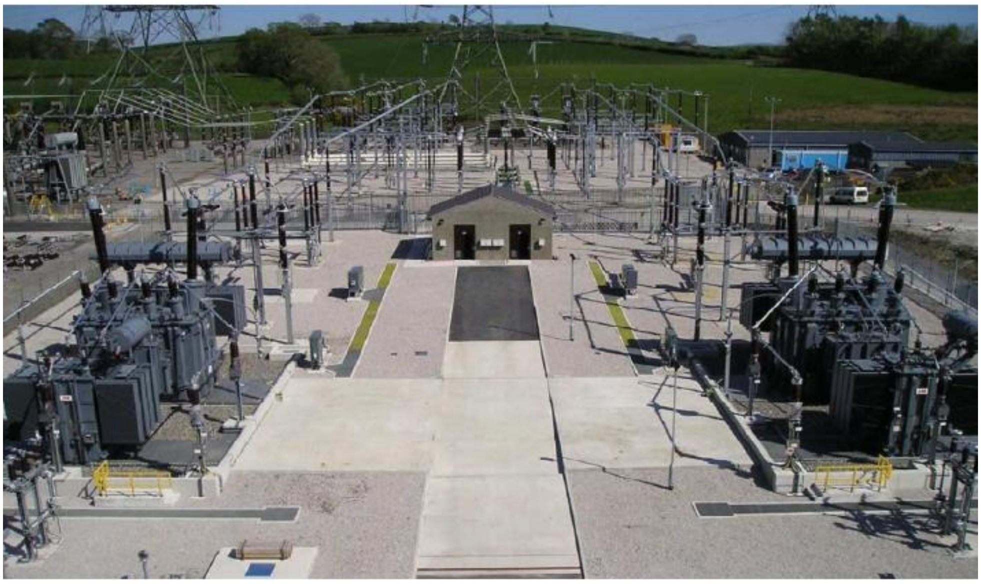


Figure 10-6: Traction substation – Outdoor

Figure 10-7 shows the typical arrangement of Gas- insulated indoor substations, where all the 110kV switch gears will be fixed inside the building and the traction transformer will be provided outside / indoor of the building.

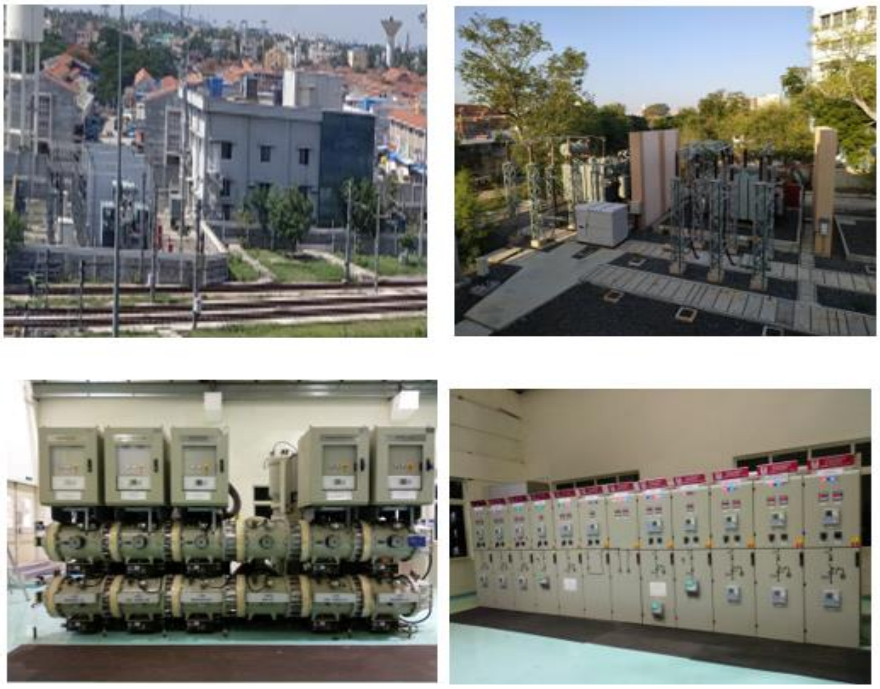


Figure 10-7: Traction substation – Indoor

The requirement of land for GIS will be considerably less but the cost of substation works will increase by nearly Rs10 Crore. Considering the high land cost in Kerala, the overall cost difference between AIS and GIS may even come down. The area required for GIS is approximately 3000 - 4000 Square meter.

10.10.2.1 Comparison between AIS and GIS

Table 10-17 shows the comparison between Outdoor (AIS)and Indoor substations (GIS).

Table 10-17 : Difference between GIS and AIS

Comparison	GIS	AIS
Media used for "Busbar" insulation	SF6	Air
Media used for "Switching"	SF6	Air, Oil, SF6 or Vacuum
Safety	More safety	Less safety
Reliability	More reliable	Less reliable
Maintenance	No maintenance required for 5 years	Every year maintenance and based on the operation
Maintenance producers	Experts required for maintenance	Experts are not required
Area	less area required	Large area required
Capital cost	High	Low
Installation	Easy and don't require much time for assembly	Require more time for assembly

10.10.2.2 Recommendation

To achieve the desired reliability, it is recommended to provide 8 nos of Traction substations (indoor and outdoor) in this corridor. This will enable to feed 2x 25 kV traction power supply to the corridor with a maximum speed of 220 kmph and the spacing between TSSs will be 70 -100 km.

10.10.3 Traction Transformer

The power is obtained from a 110 kV, three-phase, effectively earthed transmission network of the Kerala State Electricity Board, through single-phase transformers, V-connected or Scott connected transformer installed at the TSS, which will step down the 110kV to 50kV (2x25kV) or 110kV to 25kV. In 25kV traction system, a single-phase transformer is used to step down the voltage from 110kV to 25kV and the primary winding of the single-phase transformer is connected to two phases of the transmission network. In 2x25kV system, Scott connected or V- connected transformers are used to step down the voltage. The Scott and V- connected transformers are effective in reducing voltage imbalance caused by the traction loads on the transmission network of the KSEBL.

Compare to conventional lines, higher current shall be required for High-speed rails. It is proposed to have a larger capacity of traction transformer. The tentative capacity of the traction transformer is 40/54 MVA (ONAN/ONAF). The capacity of the transformer may be reviewed considering the load requirements of the corridors at the time of detailed design. To minimize the voltage fluctuations in the incoming side of traction substation, On-load tap changer (OLTC) needs to be installed. The transformer shall be designed to withstand the environmental conditions of Kerala.

10.10.3.1 Transformer connection method adopted in HSR

There are two types of transformer connection methods available for transferring 3 phase voltage to 1 phase or 2 phase voltage ie for handling a considerable amount of power. The most common connection method used for the Traction transformers in high-speed rails are Scott connection and V- connection.

Table 10-18 shows the connection method adopted for high -speed rails by major countries.

Table 10-18 : Transformer connection method adopted for High Speed Rails

Connection method	Name of country
Scott Connection	Japan, Taiwan, South Korea, France
V - Connection	France, Italy, China

Figure 10-8 shows the Scott and V- connection feeding to the High-Speed Rails. In Scott connected system, two transformers will be provided to feed the traction supply at the substation. The primary windings are connected to the three phases of the transmission network. The Scott connection evenly distributes a balanced load between the phases of the source. One transformer will feed the mainline railway supply and the other one will act as hot standby supply. In V - connection method, three transformers will be provided to feed the traction supply at the substation. The three single-phase transformers form an open delta-connection on the primary side. Out of three single-phase transformers, one transformer feeds the Overhead Contact System (OCS) on one side of the TSS, another feeds the OCS on the other side of

the TSS, and the third remains as standby. Thus, the two single-phase transformers that feed the OCS constitute an open-delta connection on the three-phase transformers network. The Scott-connected transformer and V-connected single-phase transformers are effective in reducing voltage imbalance on the transmission network.

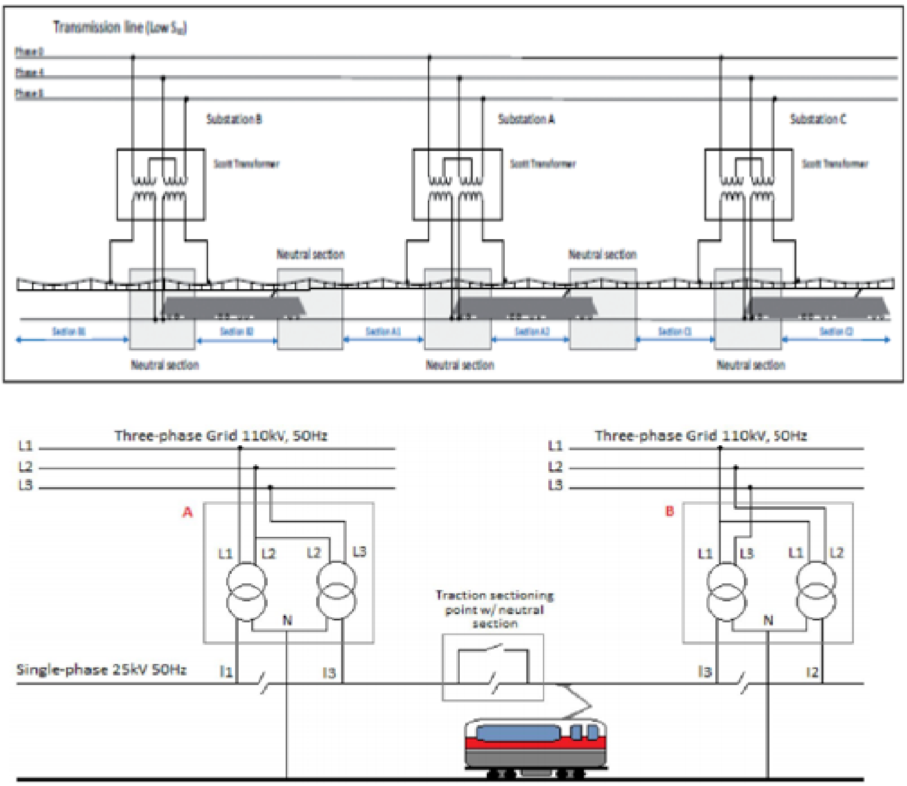


Figure 10-8: Scott and V- connection method

10.10.3.2 Calculation of voltage unbalance rate

The following formula is used for calculating voltage unbalance rate due to the connection method of the transformers

1. Single phase Transformer u = $(E_s \times I / P_s) \times 100\%$
2. V - Connection Transformer u = $(E_s \times \sqrt{}(I_a^2 + I_b^2 - I_a \times I_b) / P_s) \times 100\%$
3. Scott connection Transformer u = $(E_s \times |(I_m - I_t)| / P_s) \times 100\%$

Where,

u - Voltage unbalance rate (%)

E_s - Line Voltage (KV)

P_s - Short current apparent power (kVA)

I - Line current (Single phase in Ampere)

I_a, I_b - Line current (V- connection in Ampere)

I_m, I_t - Line current (Scott connection in Ampere)

Figure 10-9 represents the normal feeding of TSS and extended feeding of TSS, in case of one TSS failure

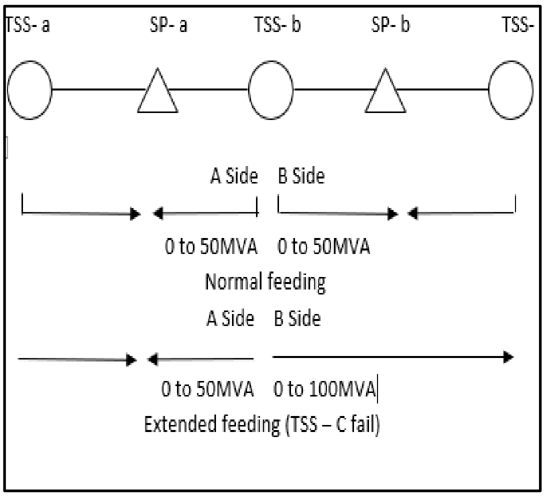


Figure 10-9: Normal and Extended feeding

Figure 10-10 shows the calculation result of the voltage unbalanced rate of different load conditions. In case of load in one direction, voltage unbalances rate is similar in any connection but in the case of loads in both directions, the voltage unbalance rate of Scott connection is lesser than V- connection.

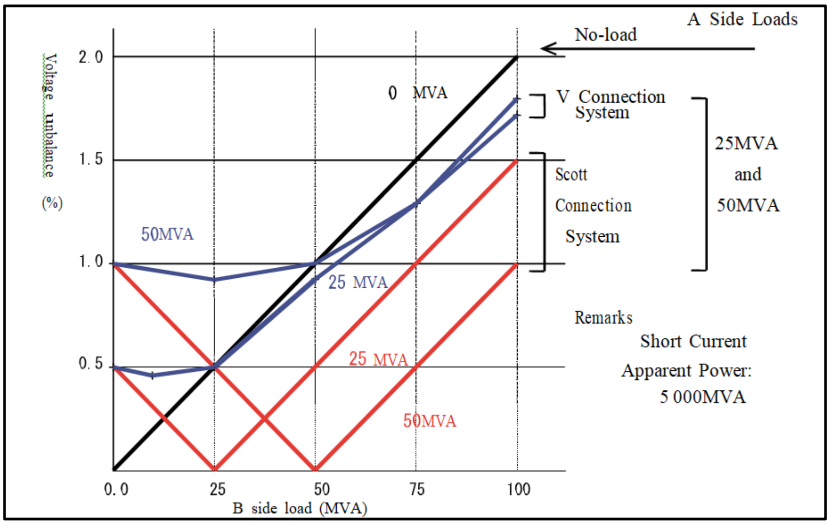


Figure 10-10: Connection method of transformer and voltage unbalance rate

To sum up the advantage of the Scott connected transformers over V- connected transformers:

The incoming circuit can be simplified.

The number of traction transformers is reduced.

The power supply voltage unbalance is reduced.

A Scott connected transformer is a type of equipment used to derive two-phase electric power from a three-phase circuit. The Scott connection evenly distributes a balanced load between the phases of the source.

10.10.3.3 The requirement of Kerala State Electricity Board Ltd (KSEBL)

The transmission authorities of Kerala are insisting southern railway, railway traction consumer, for provision of Scott connected traction transformer to reduce the level of voltage unbalance and harmonics. Indian Railways are also adopting Scott connected transformers for their traction substations

10.10.3.4 Recommendation

Considering the advantages and to comply with the requirements of power supply authority/ KSEBL, it is recommended to provide Scott connected traction transformer in substations of SilverLine.

10.10.4 Feeding System adopted for High Speed Rails

In AC traction system, return current mainly flows to the substation through track leaving a small portion, which flows through ground because of leakage of current from track to the ground. This leakage current causes a heavy interference with communication lines which are running near the track. A feeding system shall be adopted with suitability to control the outflow of current to the ground

Presently, two types of feeding systems adopted in railways and High- speed Rails, which are

a) 25 kV Traction System
b) 2x 25 kV traction System

10.10.4.1 25kV Traction System

- **25kV System**

Figure 10-11 shows the arrangement of 25kV feeding system. In this system, the power supply is fed directly to the catenary wire. Feeder droppers are provided to direct the current from catenary to contact wire. Pantograph collects the current from the contact wire and returns through the running rails.

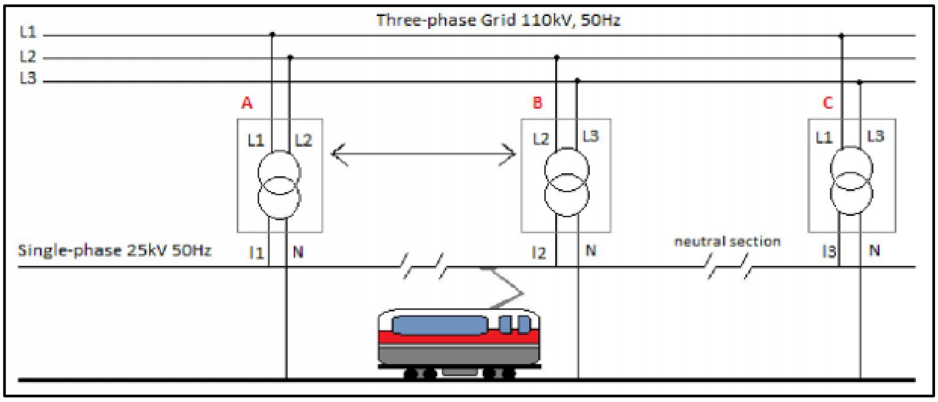


Figure 10-11: Single 25kV system

- The simplest feeding system
- Possibility of induction effect to the communication lines
- Higher rail potential than other feeding systems

➢ 25kV with Booster Transformer feeding System (BT)

Figure 10-12 shows the arrangement of 25kV with BT feeding system, in this type of arrangement booster transformers, are provided at regular intervals to avoid /nullify the inductive disturbance to the communication line. To minimise the interference, it is desirable for the return current to be carried in a return conductor located near overhead contact system. The BT will restrict the leakage current from the return rail path.

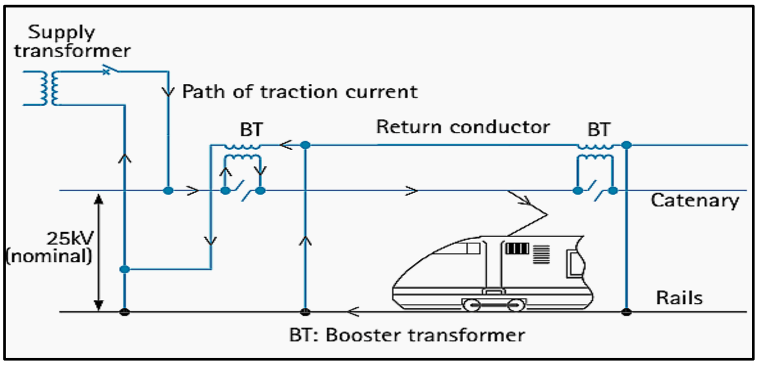


Figure 10-12: Single 25kV with Booster Transformer feeding System (BT)

- A feeding system that uses a booster transformer
- Effective in reducing induction to communication lines
- Need a Booster Transformer section
- Complicated contact wiring in the Booster Transformer system as the booster transformer system requires the sectioning at each booster transformers, which causes electrical and mechanical inconvenience for the contact wire and pantograph at high speed
- Considerable impedance in the feeding system

10.10.4.2 2x 25 kV system with Auto Transformer (AT) feeding system

1. **Figure 10-13** shows the arrangements of 2x25kV Autotransformer type feeding system, in this arrangement , The power for electric traction is supplied in AC, 50Hz single phase through 2x25 kV Auto Transformer feeding system, which has a feeding voltage (2x25kV) from the substation two times as high as the catenary voltage of the 25kV system. This high voltage power supplied from the substation through catenary and feeder wire is stepped down to the voltage by use of autotransformer (AT) installed along the track and then fed to the locomotives. The voltage between the catenary and the feeder is 50kV and the voltage between catenary and rail is 25kV.
2. The power is obtained from 220/110kV Scott connected transformer provided at the substation. The primary winding of the transformer is connected to three-phase of the 110kV three-phase earthed transmission network of the KSEBL. The Scott connected transformer is effective in reducing voltage imbalance caused by the traction loads on the transmission network of the KSEBL. The spacing between adjacent substation is normally between 70 to 100 km.
3. The load current from the substation flows through the catenary and returns to the substation through the negative feeder. Between two adjacent Auto Transformers (ATs), the load current fed from the catenary to the locomotive flows in the rail and boosted up to the feeder through the neutral tap of the two ATs.

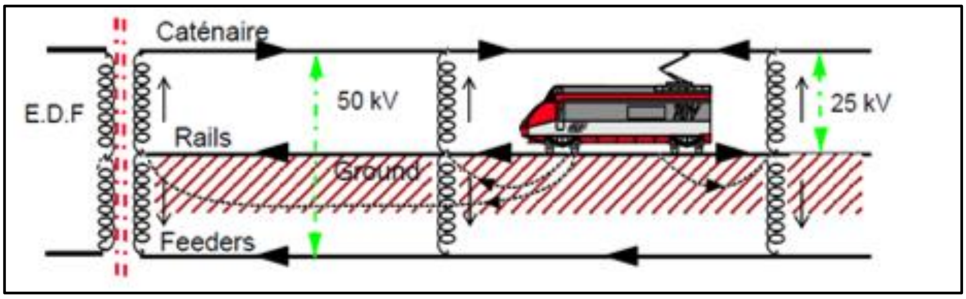


Figure 10-13: 2x25 kV Auto Transformer feeding type system (AT)

- Suitable for High-speed operation
- Suitable for supplying more power because it can carry feeding voltage higher (double) than that carried by an overhead contact line
- Less voltage drops in the feeder circuit
- The spacing between Traction substations are more
- The distance between auto transformers will be approximately 10 -15 km interval
- Interference of communication lines will be reduced/eliminated - the electromagnetic interference (EMI) emitted due to the load current in the OCS and running rails. This system has an important impact on the EMC perturbations generated by the Overhead Contact System (OCS). The current

in the OCS is about the same as in the negative feeder but in the opposite direction. As the negative feeder is hung at the top of the catenary masts, its generated magnetic field is opposing the one generated by the OCS.

- Less rail potential - The return current flowing in the rails in the sections close to the substations is much less than the corresponding figure for the single-phase system, the rail potential in these sections is reduced. Therefore, it is a safer system

10.10.4.3 Advantages of 2x25 kV system over 25 kV system

a) The distance between substations will be increased, which lower HV connections associated HV utility circuits, HV transformers and HV switch gears and investments
    - with equal volumes of traffic, reduce the line voltage drops and so improve the performance of the traction circuit.
    - With equal traffic, reduced number of substations and consequently the number of neutral sections

b) Improved voltage regulation and reduced transmission line losses

c) to reduce considerably electromagnetic and telephone disturbance concerning the residents and railway installations. Electromagnetic Interference (EMI) emitted due to the load current in the OCS and running rail is considerably reduced.

d) **Figure 10-14** shows the simplified comparison of the extent of the 25kV system and 2x25kV system. The extent of the EMI in the 2x25kV case is much reduced and would therefore have a lesser effect on the other systems and equipment at ground level.

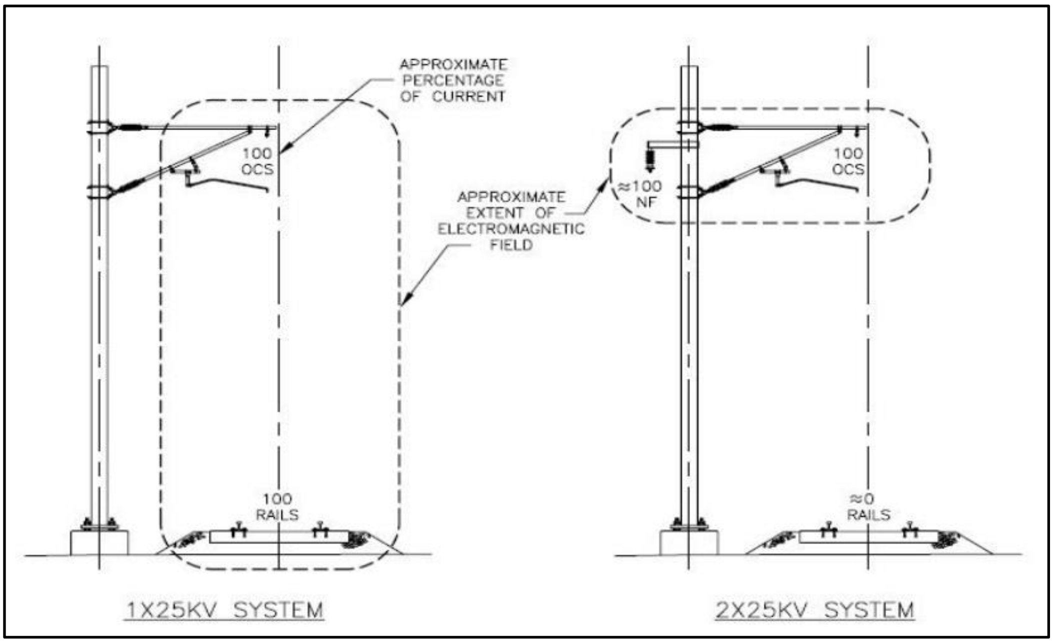

APPROXIMATE PERCENTAGE OF CURRENT
100 OCS
APPROXIMATE EXTENT OF ELECTROMAGNETIC FIELD
≈100 NF
100 OCS
100 RAILS
≈0 RAILS
1X25KV SYSTEM
2X25KV SYSTEM

Figure 10-14: Comparison of 25KV and 2x25 KV Auto Transformer feeding system (AT)

e) to present no discontinuity of contact wire at the autotransformers, whereas in the booster-transformer system, the sectioning at each booster-transformers causes serious electrical and mechanical inconvenience for the contact wire and the pantographs, particularly at high speed.

f) Improved load factor as the number of trains fed per feeding post is more

Table 10-19 shows the comparison of electrical aspects of 1x25 kV and 2x25 kV System.

Table 10-19 : Comparison of electrical aspects

Parameters	1 x 25 kV system	2x 25 kV system
Line Voltage	25kV	50kV
Line Voltage drop	A	A/3
Line Current	B	B/2
Copper loss	C	C/4
Disturbance	D	Reduced considerably

Table 10-20 shows the main parameters involved in a cost comparison.

Table 10-20 : Cost comparison

Item	Cost	
	1 x 25 kV system	2x 25 kV system
Substation	A	a < A/2
HT lines	B	b <B
Auto Transformer (AT) stations	0	c
Catenaries	D	d >D
Cables along the track	F	f <F
PTT protections	G	g <<G

Indian Railways has the experience for operating the 2x25kV feeding system for the Bina - Katni - Anupur - Bishrampur/Chirimiri line which was opened in the year 1996. Also, the Dedicated Freight Corridor (DFC) project, has adopted the 2x25kV system.

In the joint feasibility study report for the operation of High-Speed Rail from Mumbai to Ahmedabad in India, the recommended feeding system was 2x25kV autotransformer type for traction.

For the operation of HSR in Japan, Taiwan, South Korea, China, France, Spain, California and Italy, 2x25 kV feeding system is adopted.

10.10.4.4 Recommendation

Considering the advantages of 2x25 kV system and acceptance of 2x25kV feeding system for High-Speed Rail operation in international countries and in India, it is recommended to adopt 2x25 kV autotransformer type feeding system for train operation of SilverLine.

The proposed 2x25 kV traction power supply system consists of traction power substations with transformers and switching stations and paralleling stations with autotransformers, which provide 25 kV voltage to the contact line with respect to ground and catenary to negative feeder voltage is 50 kV.

10.10.4.5 Proposed system design

Figure 10-15, **Figure 10-16**, **Figure 10-17**,**Figure 10-18**,**Figure 10-19** and **Figure 10-20** represent the typical SLD of Traction substation, Sectioning diagram and typical connection diagram of 2x25 kV autotransformer type feeding system.

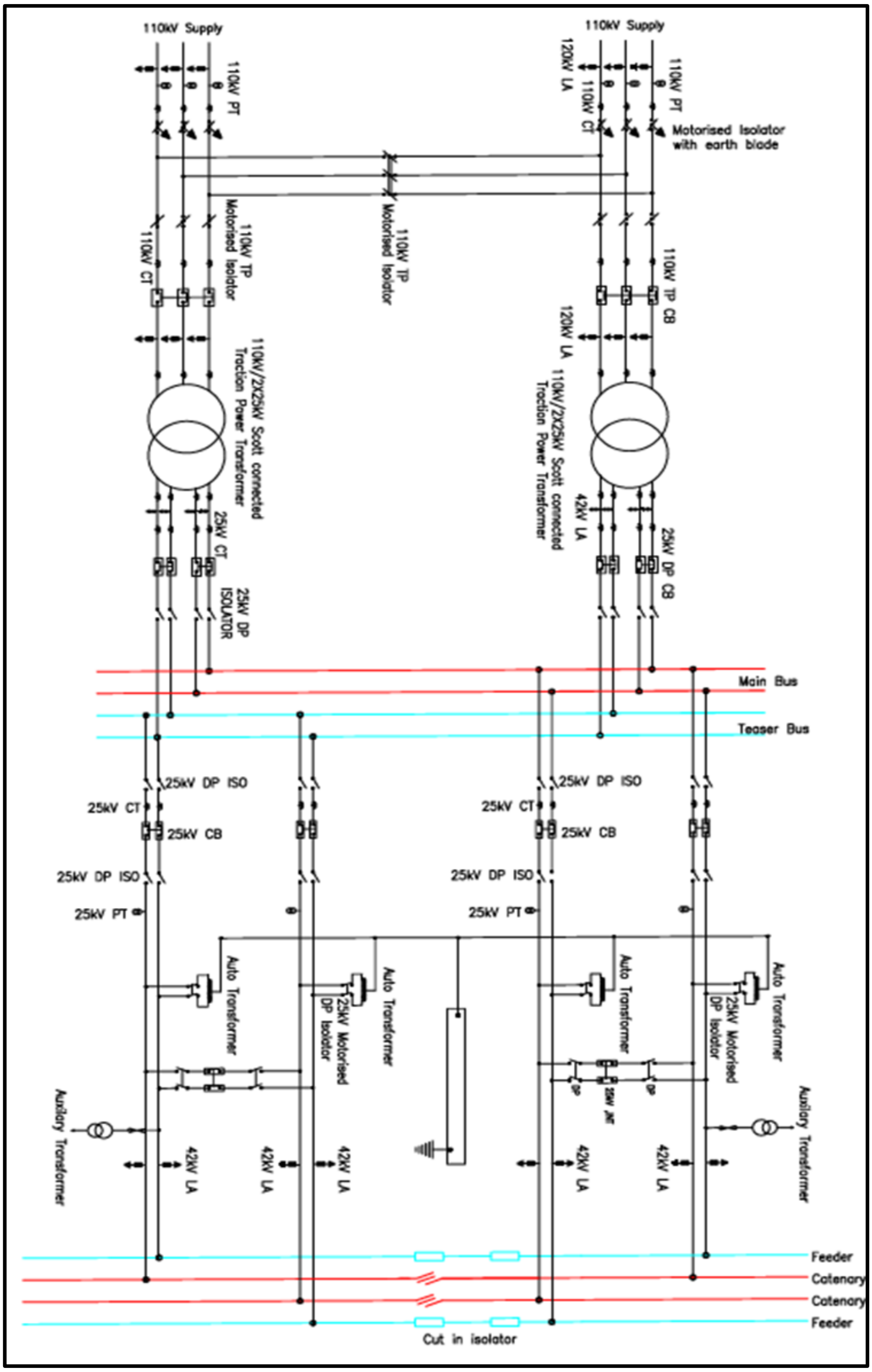


Figure 10-15: Typical single line diagram of 2x25 kV system Traction substation

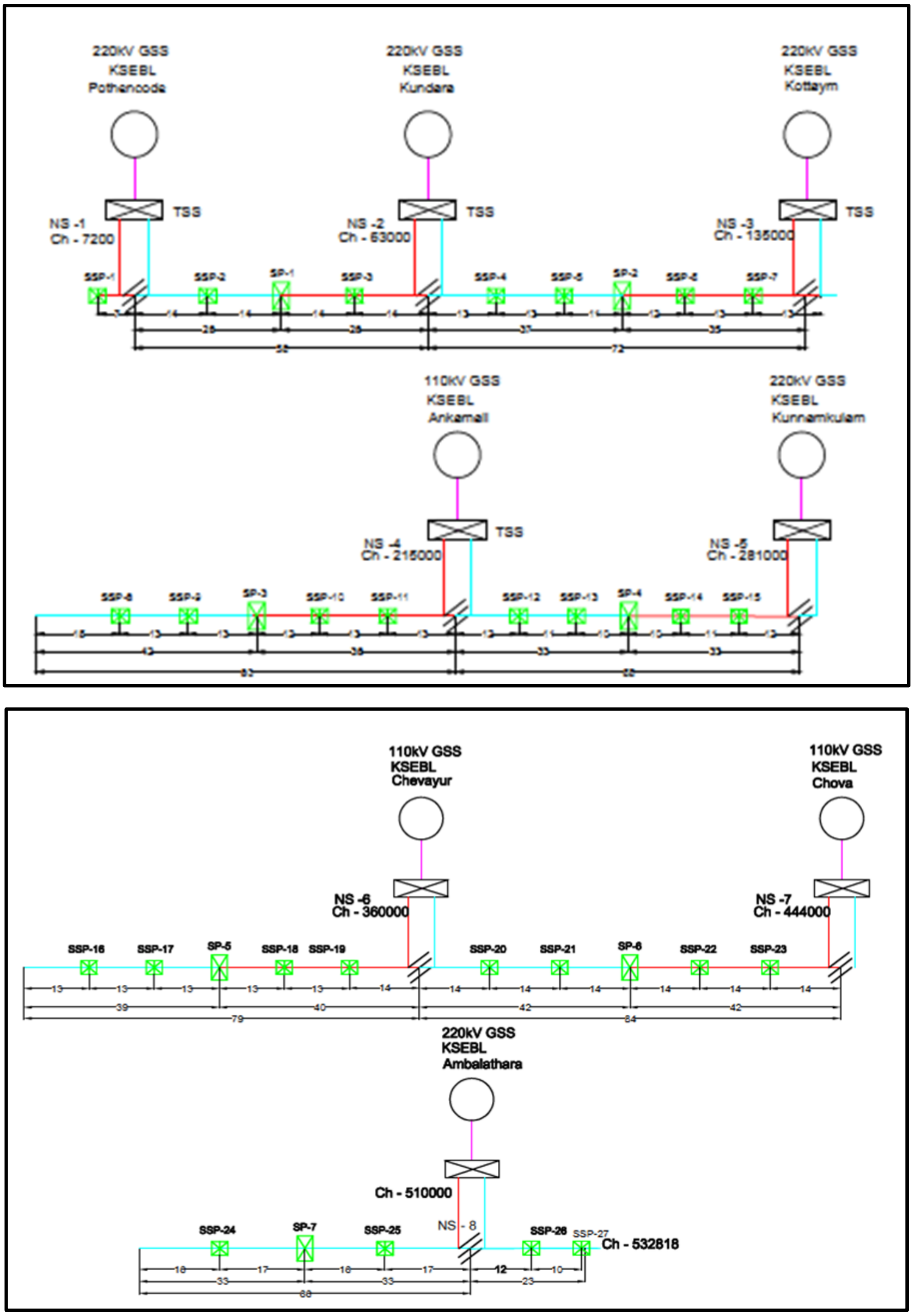


Figure 10-16: Sectioning arrangement of Overhead Contact System

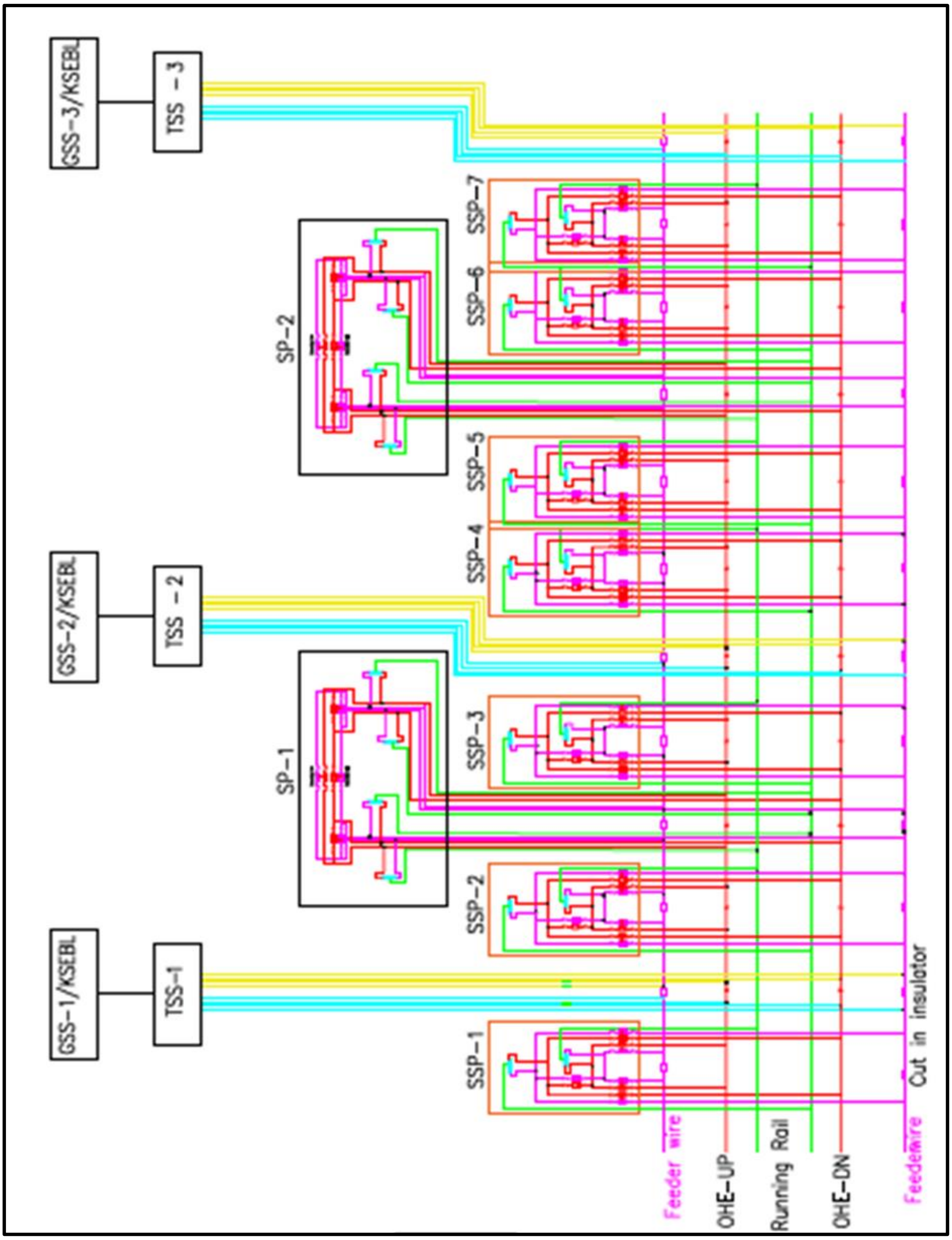


Figure 10-17: Connection diagram of Overhead Contact System (TSS - 1 to TSS- 3)

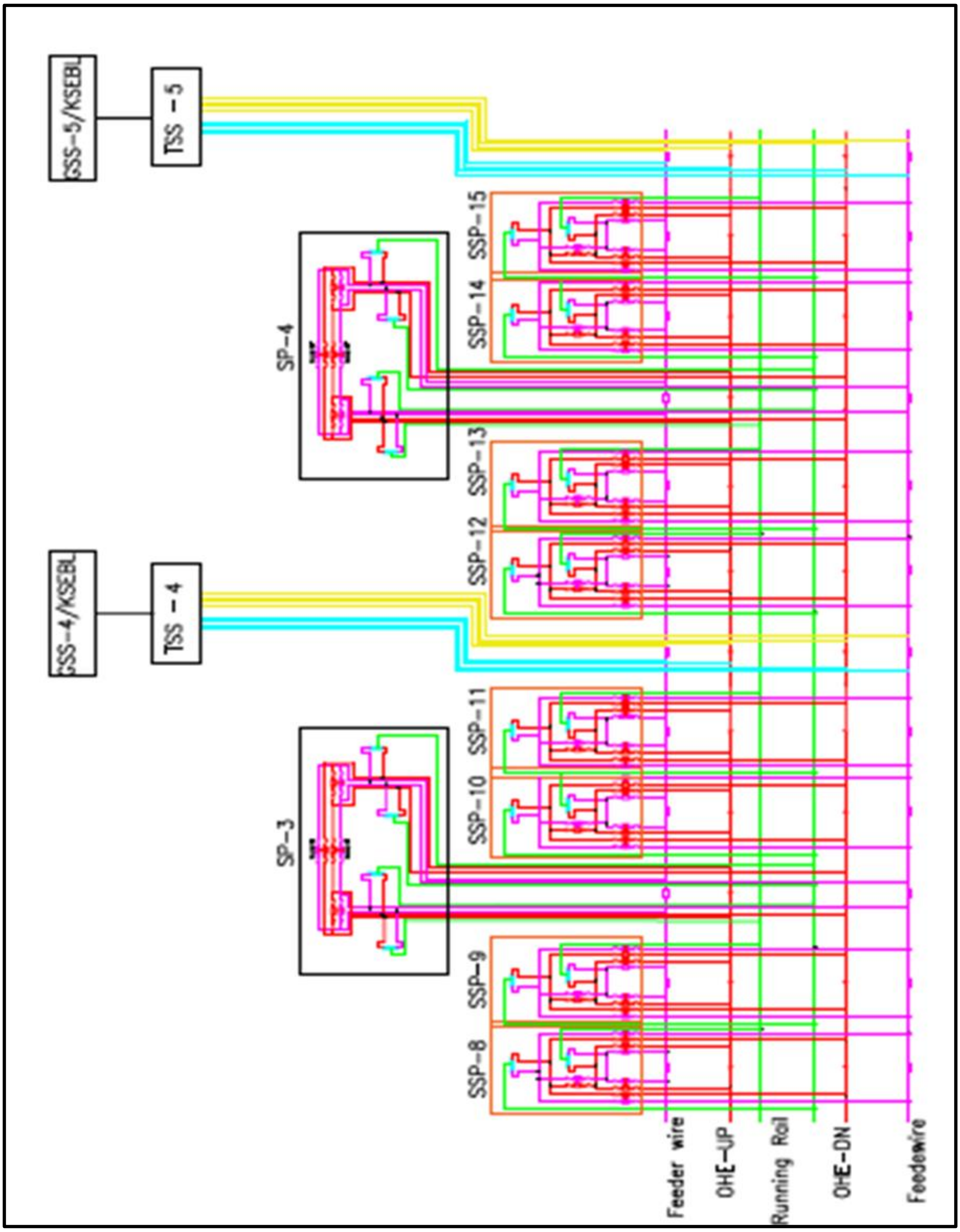


Figure 10-18: Connection diagram of Overhead Contact System (TSS-4 to TSS-5)

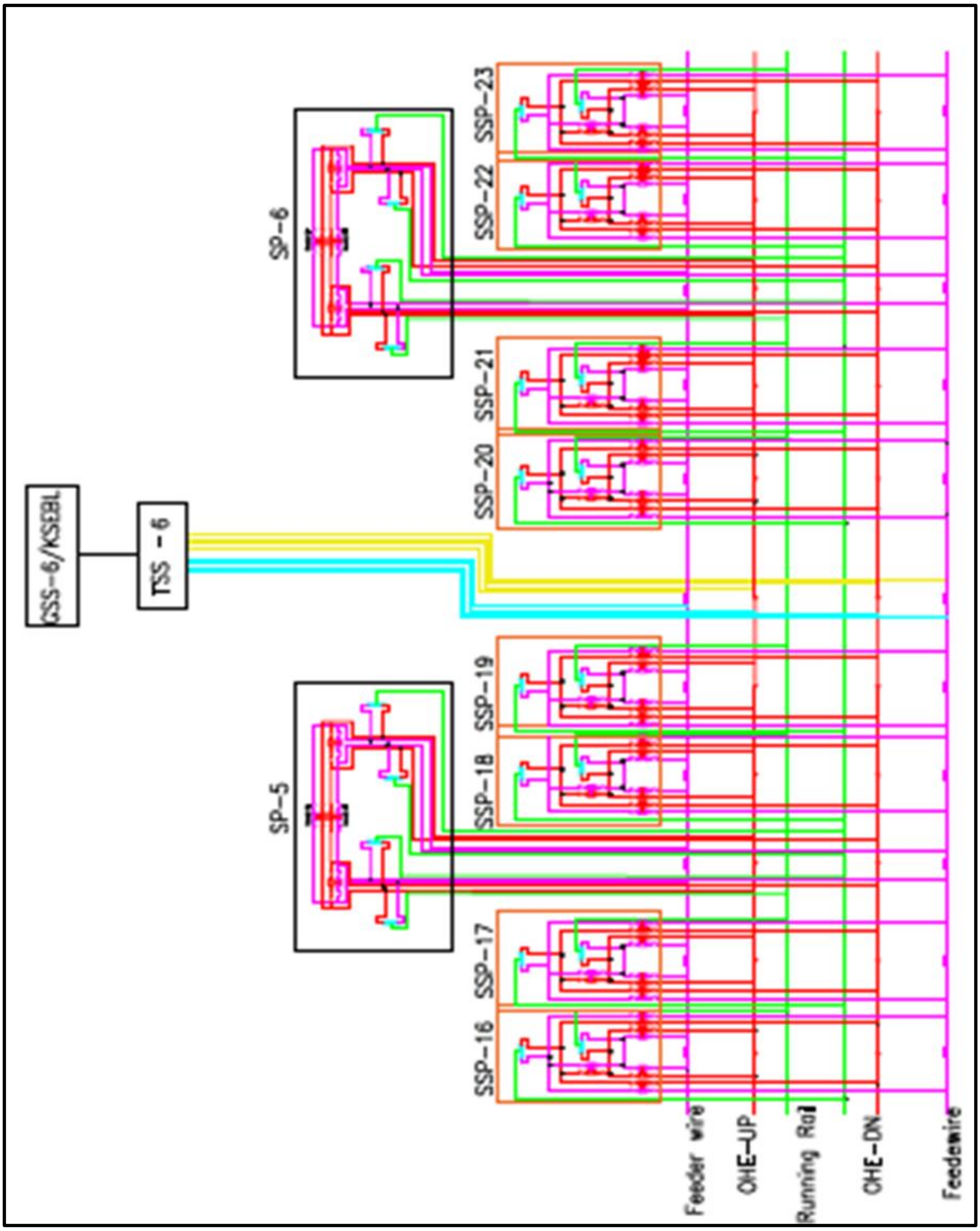


Figure 10-19: Connection diagram of Overhead Contact System (TSS- 6)

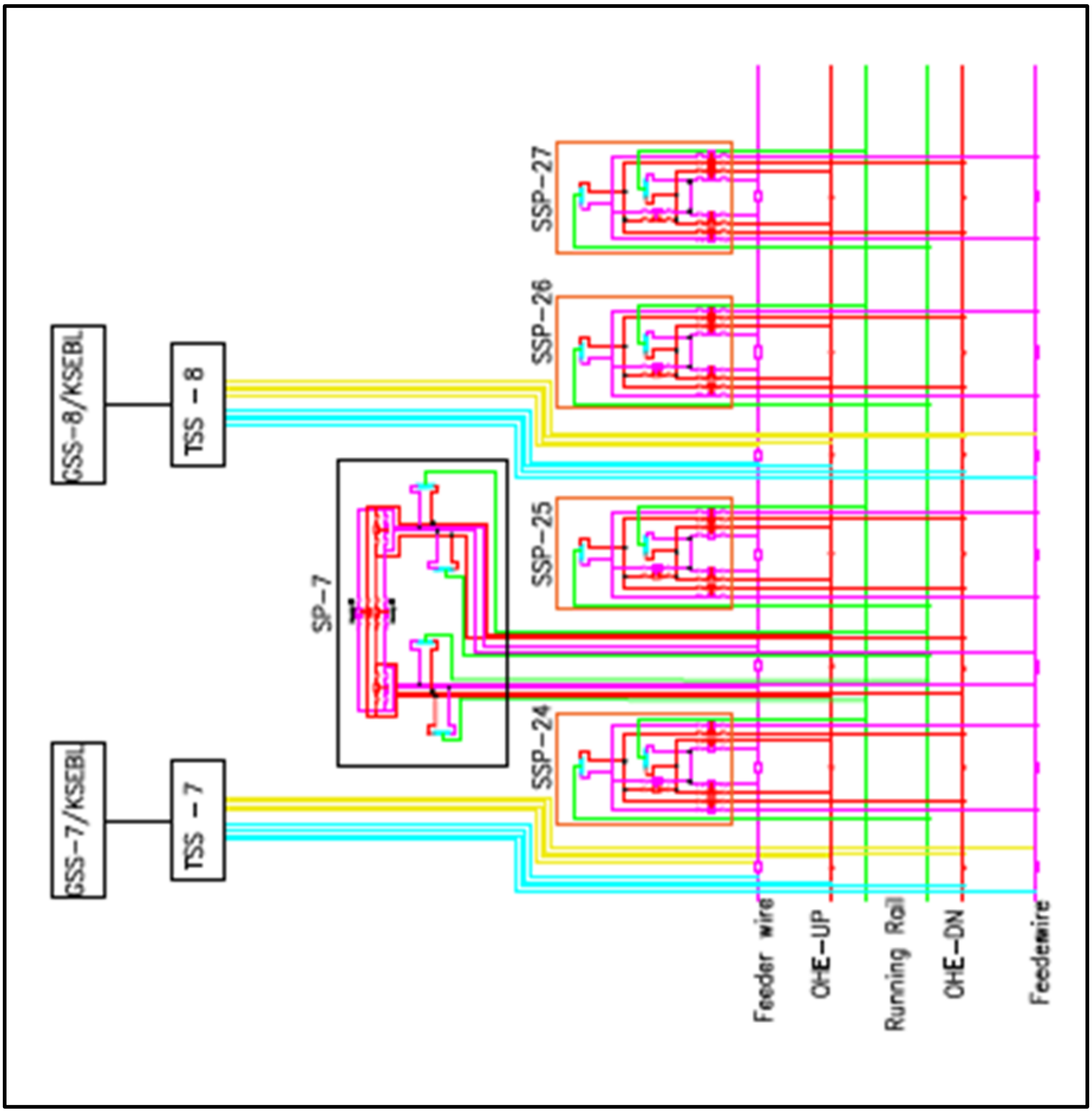


Figure 10-20: Connection diagram of Overhead Contact System (TSS-7 to TSS-8,)

10.10.4.6 Location of Traction Substation and Switching stations

Table 10-21 shows the location of TSS's and Switching Stations and the distance between them.

Table 10-21 : Location of TSS, SP and SSP of SilverLine corridor

TSS/SP/ SSP	Chainage	Inter distance in meter	Distance between TSS -TSS in meter	Distance between TSS - SP in meter
SSP - 1	0			
TSS-1	**7000**	7000	56000	28000
SSP-2	21000	14000		
SP-1	35000	14000		
SSP-3	49000	14000		28000
TSS-2	**63000**	14000		
SSP-4	76000	13000	75000	37000
SSP-5	89000	13000		
SP-2	100000	11000		
SSP-6	112000	12000		38000
SSP-7	125000	13000		
TSS-3	**135000**	13000		
SSP-8	151000	16000	80000	42000
SSP-9	164000	13000		
SP-3	177000	13000		
SSP-10	189000	12000		38000
SSP-11	202000	13000		
TSS-4	**215000**	13000		
SSP-12	227000	12000	66000	33000
SSP-13	238000	11000		
SP-4	248000	10000		
SSP-14	258000	10000		33000
SSP-15	269000	11000		
TSS-5	**281000**	12000		
SSP-16	294000	13000	79000	39000

TSS/SP/ SSP	Chainage	Inter distance in meter	Distance between TSS -TSS in meter	Distance between TSS - SP in meter
SSP-17	307000	13000		
SP-5	320000	13000		
SSP-18	333000	13000		40000
SSP-19	346000	13000		
TSS-6	**360000**	14000		
SSP-20	374000	14000	84000	42000
SSP-21	388000	14000		
SP-6	402000	14000		
SSP-22	416000	14000		42000
SSP-23	430000	14000		
TSS-7	**444000**	14000		
SSP-24	460000	16000	66000	33000
SP-7	477000	17000		
SSP-25	493000	16000		33000
TSS-8	**510000**	17000		
SSP-26	522000	12000		
SSP-27	532000	10000		

10.10.5 Overhead Contact System (OCS)

The Overhead Contact System (OCS) will provide electric traction power to the pantographs of the electric trains therefore configured as a 25kV-0-25kV arrangement with a catenary at a nominal voltage of 25kV to ground and a negative feeder, at a nominal voltage of 25kV to ground but in phase opposition with the catenary. Current collectors are electrically conductive and allow current to flow through to the train and back to the substation through negative feeder wire. The OCS shall transfer electric power from the substations to the trains under all operating conditions and shall provide reliable operation under all environmental conditions. The type of overhead equipment to be adopted is dependent on the requirement of power transfer, maximum operating speed, the spread of speed among various trains in the corridor (i.e. whether the corridor is being used for mixed operation or dedicated high speed running), number of pantographs per train and their spacing. OCS comprises of overhead wires including contact wire, catenary, feeder wire, earth conductor, supports, foundations, auto tensioning arrangements, electrical switches and isolators and other equipment and assemblies. **Figure 10-21** represents typical OCS feeding arrangement of HSR.

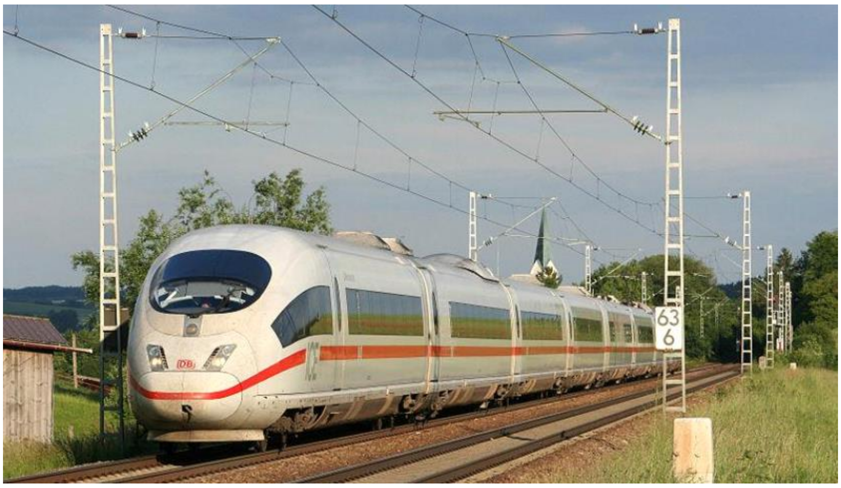


Figure 10-21: Typical OCS feeding arrangement of HSR

The OCS system shall always be located within the pantograph range, and the pantograph shall maintain contact with the OCS to collect uninterrupted good quality power at all times. Following points shall be considered while designing the OCS

- Must have the characteristics of meeting train speed and current requirements
- Must be at a uniform height above the rail to optimize pantograph power collecting characteristics, so entire equipment must have uniform spacing constant and bending rigidity
- The future performance capability to be anticipated and allowed for the design, including any allowances for over speeding
- The frequency of train services
- The operational speed for main and station tracks
- Track gradient profile and location of the route including turnouts and transitions
- Must have minimum vibration and motion to ensure smooth pantograph passage during SilverLine operation including strong wind condition
- Must have the strength to withstand vibration, corrosion, heat, etc., while maintaining balance with reliability and operating life span

The overhead contact system design shall be based upon the consideration of the electrical characteristics of the power supply system design, including

- Nominal voltage and frequency, in accordance with IEC 60850
- Short - circuit current details

- Required current rating
- Required impedance for ac/dc systems
- Proposed feeding system
- Proposed return system
- Earthing and stray current protection following IEEE-80, IEC -62128
- Requirements for over-voltage protection
- Insulation coordination

Two major safety-related matters are highlighted with the Overhead Contact System:

- Avoiding OCS equipment falling on the ground and platform
- Avoiding electrocution and short circuit.

In the first case, comprehensive design rules and design standards should be issued to make sure that the design of the mast and foundation is compatible with the environmental conditions. The surveillance and maintenance of the OCS is a major issue to address with great care. In the event of a short circuit, the power supply should be cut- off immediately. The design performance of the SilverLine OCS shall allow guarantee and demonstration of a very high level of Reliability, Availability, Maintainability and safety through a RAMS analysis.

The safety and technical requirements of OCS shall be as follows:

- Design standards shall make sure that the mast and foundation are compatible with the environmental conditions;
- The OCS system provided for SilverLine should be safety proven system and be designed for the maximum credible winds;
- When installed within air traffic control zones, the maximum allowable height of the OCS and its support structures shall be determined and complied with Civil Aviation Regulation;
- Terminal pole of OCS shall be located at a proper point behind the end of rail; all the other devices with high potential will not be located beyond buffer stop or the end of side-track;
- OCS grounding device for emergency use shall be provided on each train, at passenger stations, depots and tunnel. At every tunnel portal and every emergency exit, two grounding devices shall be accessible only to authorized personnel and must be used following approved procedures;
- To allow bi-directional working, enabling trains to continue operation under emergency conditions and to facilitate routine OCS maintenance, the OCS shall be divided into electrical sections and sub sections.

- The provision of the lightning protection system, which includes protective devices at exposed points of the installation, grounding and return current of the power supply system, shall be provided.
- To facilitate operations and maintenance activities, the OCS shall typically be equipped with non-load break motor operated disconnect switches at feeding points, which can be operated both locally onsite and remotely through SCADA system.
- In case of any routine /corrective maintenance, the authorized O&M personnel must ground the OCS at all portals using grounding device before starting the work.

10.10.5.1 Types of catenary system

There are 3 types of catenary system adopted for mainline railways and High-Speed railways

- Simple catenary system
- Simple catenary with stitch wire system (Y- stitch)
- Compound catenary system

10.10.5.1.1 Simple catenary system

Figure 10-22 shows the arrangement of a simple catenary system. This system consists of catenary, droppers and contact wire. The simple catenary system with weightier conductors, heavier tension and a sag (1/1000 of span) will be used for High Speed Rail operation. This catenary system is adopted in France (TGV Atlantic line), Japan, Italy, China and South Korea for the operation of High-Speed Rails.

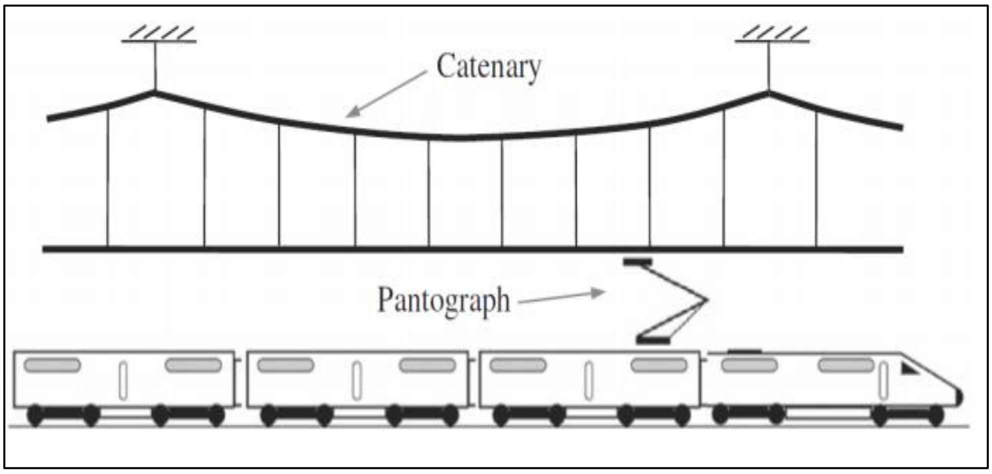


Figure 10-22: Simple catenary system

In France, simple catenary system was adopted for the TGV Atlantic line, which was commissioned in 1989 with commercial speed of 300kmph, TGV - Nord in 1993 , TGV - Mediterranean in 2001 and TGV - Est, they made modification of catenary wire(increased size of catenary) and made the operation speed up to 350kmph . In Korea, KTX - Kyungbu HSR line, which was commissioned in 2004 is running with the commercial speed up to 310kmph. **Table 10-22** shows the configuration of simple catenary used in France and Korea.

Table 10-22 : Configuration of simple catenaries

Item	TGV - Nord (France) KTX - Kyungbu (Korea)	TGV - Est
Operation Speed	300 kmph	350 kmph
Catenary System	Simple	Simple
Catenary wire	65mm^2 Bz	116 mm^2 Bz
Tension of catenary wire	14kN	20 kN
Contact wire	150 mm^2 Cu	150 mm^2 Cu Sn
Tension of contact wire	20kN	26kN

10.10.5.1.2 Simple catenary with stitch wire system (Y- stitch)

Figure 10-23 shows the arrangement of simple catenary with stitch wire system. This system consists of a Y-stitch wire introduced between the catenary and contact wire. The height difference of contact wire between mid-span and supports will be compensated by using this type of OCS. When the temperature change takes place, the vertical movements of the points, where the stitch wire is fixed to the uncompensated catenary wire, in conjunction with the change in catenary wire length and the tensile force, causes the contact wire at the support to be raised and lowered similarly to the height changes at the middle of span. The spring effect of the stitch wire and hanger arrangement enhances the elasticity of the catenary at the support and provides for a better match with the mid-span elasticity of the catenary, thereby providing improvement in the quality of current collection. In Germany, this system is adopted for the operation of High-Speed rails in operation from Cologne and Frankfurt at the operation speed of 300kmph.

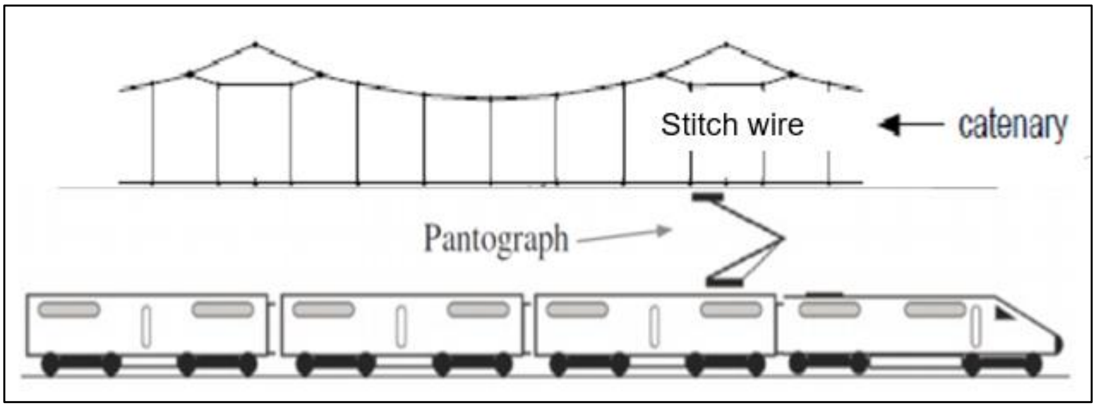


Figure 10-23: Simple catenary with stitch wire system (Y- stitch)

10.10.5.1.3 Compound catenary system

Figure 10-24 represents the arrangement of the compound catenary system. This system consists of one main catenary, auxiliary catenary, and contact wire. The auxiliary catenary wire is placed between main catenary and contact wire. Auxiliary catenary connects the main catenary and contact wire is hung on the auxiliary catenary using special type dropper called loop type dropper. This arrangement will help to eliminate the variations in elasticity. This arrangement has good running characteristics, but this type of arrangement is costly due to the increase in material cost and higher installation costs. This system is introduced in HSR of Japan since 1964. This system is most suitable for running a high speed up to 350kmph.

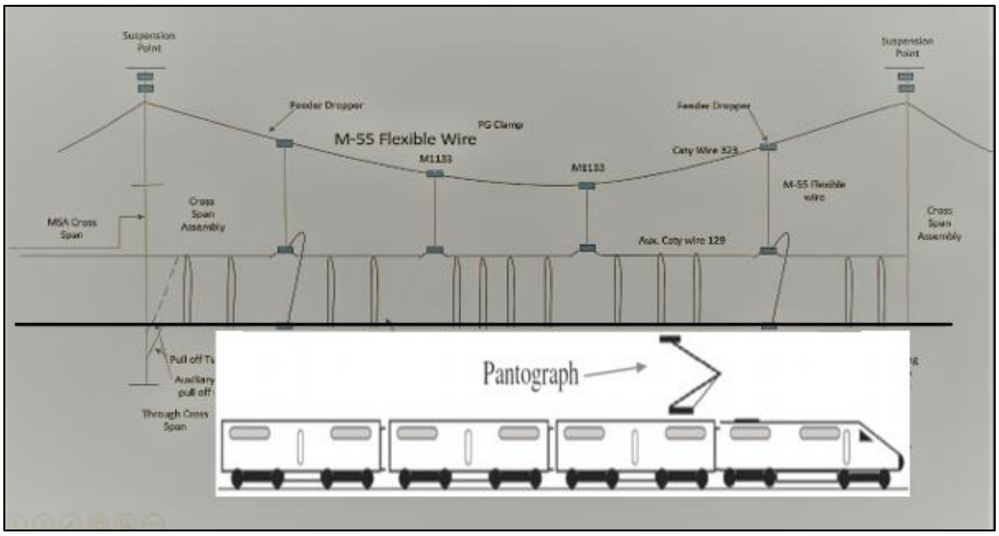


Figure 10-24: Compound catenary System

Table 10-23 shows the type of overhead equipment adopted in main countries, which operates high-speed rails.

Table 10-23 : Types of overhead contact system adopted in different countries

Type of Overhead equipment	Name of Country
Simple Catenary	France, Japan, UK, Italy, China, South Korea
Simple Catenary with Stitch wire	Spain, Germany, China
Compound Catenary	Japan, Taiwan

10.10.5.2 Design of Overhead Contact system

The following points shall be considered, while designing overhead contact system. The simulation shall be validated under EN - 50318. The measurements shall be in accordance with EN -50317

a. Wave propagation velocity

The square root of the ratio of the contact wire tension to the weight per unit length represents the velocity of the lateral wave propagating along with the wave. The OCS shall be designed to ensure that the operational speed of the line is 70% of the wave propagation velocity (EN 50119)

$V_w = \mathrm{Sqrt}\,(T / \rho)$, $V_o \leqq 0.7 \times V_w$

- Vw : Wave propagation speed [m/s]
- T : Tension of contact wire [N]
- ρ : specific mass of contact wire [kg/m]

b. Elasticity and variation

The OCS shall be designed such that there is a small variation (u) of the elasticity (e). These values describe the variation u

$U = (e_{max} - e_{min}) / (e_{max} + e_{min}) \times 100\ \%$

The elasticity and its variation depending upon the configuration of the contact line. For the OCS following factors shall be considered

- Number of contact and catenary wire
- The tension of the contact and catenary wire
- Span length
- Use of stitch wires
- Type of support
- Type, number and position of droppers

c. Vertical movement of contact line point

The contact point is the point of the mechanical contact between a contact strip and a contact wire. The overhead line shall be designed in such a way that the vertical height of the contact point above the track is as uniform as possible along the span length. This is essential for high-quality current collection

d. Quality of current collection

Pantograph and OCS shall be designed and installed to ensure acceptable current collection performance at operating speed and whilst at a standstill

The life cycle of the contact strips and contact wires depends on

- Dynamic behaviour of the OCS and pantograph
- Current flow
- Contact area and number of contact strips
- The material of contact strips and contact wire
- Speed of the train, the number of pantographs in operation and distance between them
- The geometry of the contact line
- Environmental and their uniformity
- Contact wire tensile load
- Pantograph design and contact force

e. Contact forces

The OCS shall be designed to accept maximum permissible contact forces between the pantograph and the contact wire. The minimum contact force shall be positive to ensure that there is no loss of contact between the pantograph and the overhead contact line. The criteria of the contact wire lifting force range is given in Table 10-24.

Table 10-24 : Criteria of the contact wire lifting force

System	Speed	Contact force	
	(km/h)	Maximum(N)	Minimum(N)
ac	<200	300	>0
ac	>200	350	>0

10.10.5.3 Characteristics of overhead equipment for high-speed rails

Table 10-25 : Characteristics of overhead equipment adopted for high-speed rails

Item		Japan	France		Germany	Italy
			TGV Southeast	TGV Atlantic		
Catenary Type		Compound type	Stitched and simple catenary	Simple catenary	Stitched and simple catenary	Stitched and simple catenary
Standard Span (m)		50	63	63	65	63
Standard wire height (m)		5	4.95	4.95	5.3	4.95
Wire grade	Suspended	St 180mm^2 (1.45 kg/m)	Bz 65mm^2 (0.59 kg/m)	Bz 65mm^2 (0.59 kg/m)	Bz1170 mm^2 (0.63kg/m)	Bz 65mm^2 (0.59 kg/m)
	Auxiliary Suspended	Cu 150 mm^2	Bz 35mm^2	-	Bz1135 mm^2 (0.31kg/m)	Bz 35mm^2
	Contact wire	Cu Sn170 mm^2 (1.511 kg/m)	Cd Cu 120 mm^2	Cd Cu 150 mm^2 (1.33kg/m)	Cu Ag 120 mm^2 (1.08 kg/m)	Cu Ag 151.7 mm^2 (1.35 kg/m)
Contact line total density (kg/m)		4.34	1.65	1.92	1.71	2.77 x 2
Catenary wire tension	Suspended (N)	24500	14000	14000	15000	18400
	Auxiliary suspended (N)	14700	4000(stitched wire)	-	2800(stitched wire)	2900(stitched wire)
	Contact wire (N)	14700	14000	20000	15000	14700

Item		Japan	France		Germany	Italy
			TGV Southeast	TGV Atlantic		
	Total Tension (N)	53900	28000	34000	30000	33100 x 2
Wave propagation velocity of contact wire (km/h)		355	414	441	424	376
B (Train speed/wave propagation velocity)		0.68,0.76 (240,270/355)	0.65 (270/414)	0.68(300/441)	0.59 (250/424)	0.65 (250/376)
Pre-sag		None	1/1000	1/1000	1/1000	1/1000

Table 10-25 shows the characteristics of OCS adopted for High- speed rails in different countries. The most critical constants for the mechanical performance of the overhead line are the weight and tension per unit length, the total tension is relative to the push-up force of the pantograph and is closely related to the vertical motion of the overhead line. The square root of the contact wire tension to the weight per unit length represents the velocity of the lateral wave propagating along the wire. This is the most important parameter in overhead line design. In Japan, compound catenary equipment consisting of three longitudinal wires is used for high - speed rail operation whereas simple or stitched catenary equipment is used in Europe. Compound catenary systems feature less pantograph vertical motion and larger current capacity but require a larger number of components resulting in a more complex design. In Europe, pre - sag is often used to compensate for the large vertical motion of the pantograph in the simple catenary system. Pre-sag refers to a special design feature in which the height of the contact wire is lower at the centre of the span by equal to around 1/1000 of the span. Normally, the contact wire height is 20 or 30 mm lower than the supports at the centre of the span, thereby suppressing the pantograph vertical motion. This design is effective for the overhead line on the French and German high - speed lines which have large amplitude but is less effective for the overhead line with small amplitude like the shinkansen and the Italian high-speed line

10.10.5.4 Recommendation

SilverLine from Thiruvananthapuram to Kasaragod is designed to cater to the speed of 220 kmph and extendable to 250 kmph in future. In the above comparison, it is understood that, the compound catenary system is adopted in Japan and Taiwan, where the span length is limited to 50 meters. whereas in other countries like France, Italy, China and South Korea simple catenary system is used to run the HSR operation with the operation speed up to 300kmph. Due to the advantages of saving the construction cost, easy maintainability, reliability and international practice for adopting simple catenary system for HSR operations, it is recommended to have the **simple** catenary system for SilverLine operation to cater the speed of 220 kmph and extendable to 250 kmph in future.

Table 10-26 shows the details of the proposed system of this project.

Table 10-26 : Proposed Overhead Contact System for SilverLine

Item	Main line	Depot and Siding
Type of Overhead Contact System (OCS)	Simple catenary	
Catenary wire	120mm^2, Cu alloy	65mm^2, Cadmium Cu
Contact wire	150mm^2, Cu alloy	107mm^2, Hard drawn Cu
Negative feeder	288 mm^2, Aluminium	
Standard span	54 - 63 meter (normally)	

10.10.6 2x25 kV OCS Arrangement

The OCS for SilverLine constitutes of the following conductors supported on the OCS poles and cantilevers suitable for SilverLine rail operation

1. Catenary wire
2. Contact wire
3. Negative feeder wire
4. The Aerial Earth Conductor (AEC) mounted at the top at each pole and connected to the rails
5. The Buried Earth Conductor (BEC) is normally laid in the ground just close to the track rails. All the metallic OCS support structure are connected to this conductor, which act as additional earth conductor

The clearance between rail to contact wire of Open route, tunnel, Cut and cover, Viaduct and ROB are explained in Figure 10-25, Figure 10-26, Figure 10-27, Figure 10-28 and Figure 10-29.

10.10.6.1 2x25 kV OCS arrangement on open route

Figure 10-25 represent the OCS arrangements of SilverLine on the open route

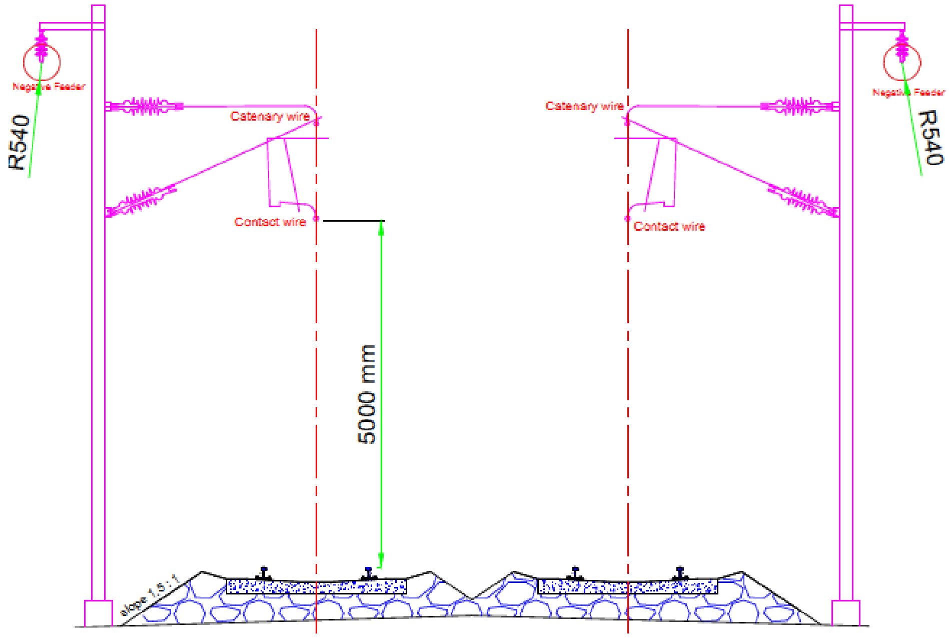


Figure 10-25: OCS arrangement in at grade

10.10.6.2 OCS arrangement on Tunnels

Figure 10-26 represent the OCS arrangements in tunnels. In tunnels, the catenary is suspended to the vault of the tunnel. The equipment can be either axial or lateral. The below figure shows the arrangement of OCS in tunnels.

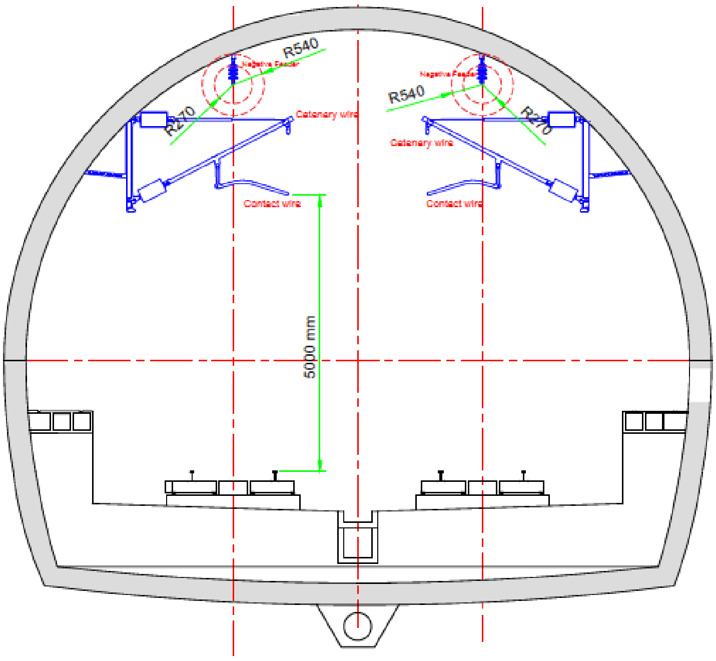


Figure 10-26: Typical arrangement of OCS in Tunnels

In the tunnel, electrical clearance between overhead line and negative feeder wire is difficult to maintain, the negative feeder wire can be converted to insulated cables or some other fixing arrangement can be made available to run the feeder wire.

The short space available in height become the following implications:

- Reduced distance between supports (increasing by this way the number of supports)
- Reduced distance between anchors
- Specific anchors
- Protection of conductors

Every tunnel is framed by two sectioning devices, disposed of as close as possible to the tunnel ends. If a tunnel is less than 1000m, a fix point is set around the middle of the tunnel. And when the tunnel length is more than 1000m, one or more mechanical sectioning(s) is/are required inside the tunnel.

10.10.6.3 OCS arrangement on Cut and Cover

Figure 10-27 represent the OCS arrangements on cut and cover. The fixing arrangement of catenary and negative feeder is marked in the figure.

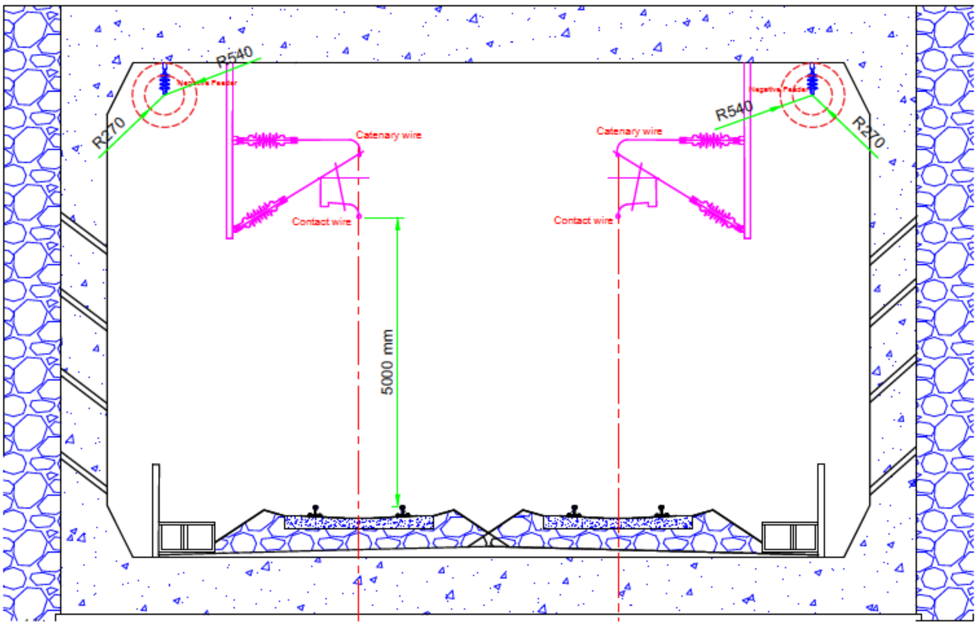


Figure 10-27: Typical arrangement of OCS on Cut and Cover

10.10.6.4 OCS arrangement on Viaducts

On viaducts, the OCS are mounted according to the following;

- Poles are commonly fixed directly on the infrastructure, the solution for the anchorage depends on the type of viaduct. It can be on the top, if viaduct is wide enough otherwise it can be on the side.

- Anchors of the line shall be equipped with a stop fall device to avoid any big damage for the infrastructure in case of any catenary failure.

Figure 10-28 shows the OCS and pole arrangement on the viaduct

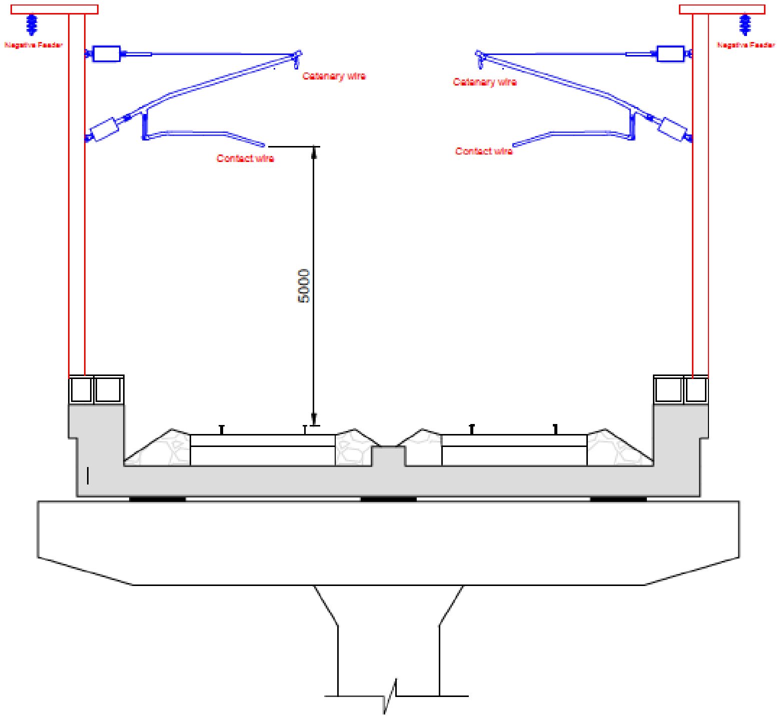


Figure 10-28: Typical OCS support structure on Viaduct

10.10.6.5 OCS arrangement on ROB

Figure 10-29 shows the OCS arrangement of ROB

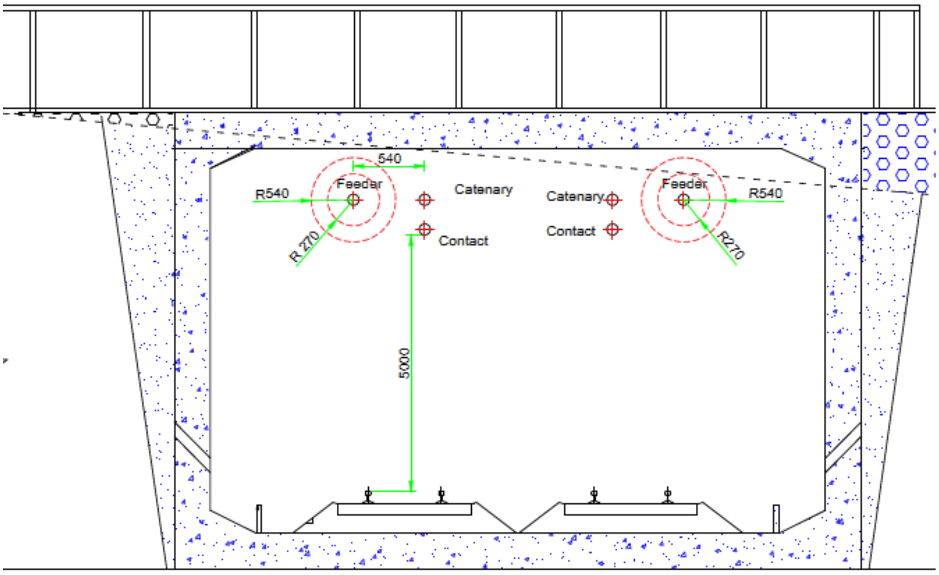


Figure 10-29: Typical OCS support structure on ROB

10.10.6.6 Electrical clearance

The clearances to a structure must include the provision of the following

1. The electrical clearances between the earthed provision of the structure and overhead equipment and between the live parts of the equipment and pantograph
2. The electrical clearance between the live parts of the overhead equipment and kinematic load gauge
3. The up-lift of the live overhead equipment and pantograph when the two areas in contact, considering the design of the equipment and speed of the traffic
4. Lateral movement of the pantograph
5. The construction depth of the live parts of the overhead equipment (axial distance between the axis of the catenary wire and contact wire of overhead equipment)
6. The tolerances of installation and maintenance of overhead equipment
7. Tolerances in installation and maintenance of the track alignment height and cross -level
8. The effects of horizontal and vertical curvature, including super elevation
9. The kinematic load gauge for the line concerned

In 2x25kV AC system, there is a 180-degree phase difference between live parts connected to the negative feeder and live parts connected to the catenary system. The electrical clearance shall be followed as per the EN - 50119. As per EN -50119 in 25kV ac traction, the recommended air clearance between earth and live parts of the overhead contact system are

Static conditions - 270 mm

Dynamic conditions - 150 mm

The recommendation provided in EN - 50119 for adjacent live ac contact line of differing voltage phases are

Static conditions - 540 mm

Dynamic conditions - 300 mm

As per letter Number 2011/CEDO/SD/IRSOD/Elect/02 dated 08.11.2012 of Ministry of Railways, Amendment to para 2&4 of Chapter V.A : Electric Traction , the Minimum vertical distance between any live part of overhead equipment or pantographs and parts of any fixed structures (earthed or otherwise) or moving toads /shall be as under;

Long duration - 250mm
Short duration - 200 mm

10.10.7 Neutral Section

A neutral section shall be provided for sections that have different phases of power supply / phase displacement between main and teaser winding of Scott connected transformer to prevent the pantograph from causing short-circuit/bridging to the different phases of power supplies when a train pass. Neutral sections are installed at sub-station locations and in the middle of the intervals between two adjacent sub-stations. Neutral sections are necessary to avoid power from one feeder inadvertently passing via the OCS to another feeder. Typical arrangement of neutral section is provided in **Figure 10-30** .

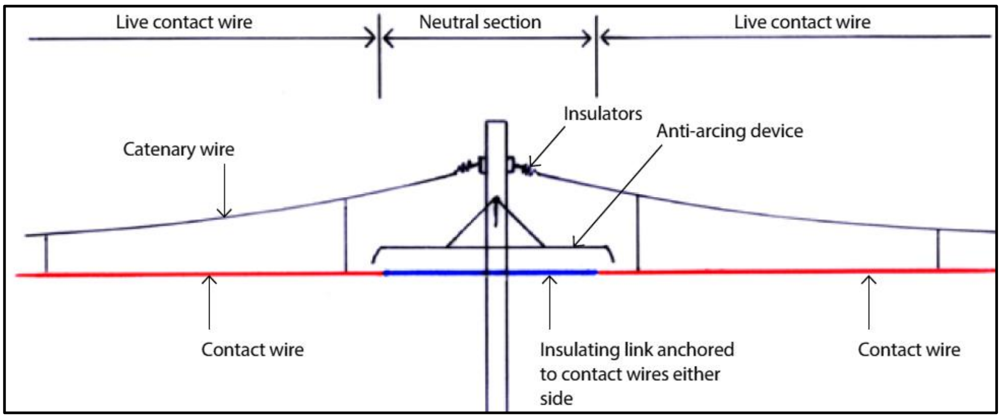


Figure 10-30: Typical arrangement of neutral section

Presently two types of neutral sections are being used for high - speed rails in worldwide

a. Power Supply Installation (PSI) side switching method (Change over section system)
b. On- board circuit breaker (CB) off method.
    a. Long Neutral Section
    b. Split Neutral section

Figure 10-31 shows the different types of neutral sections used for HSR lines.

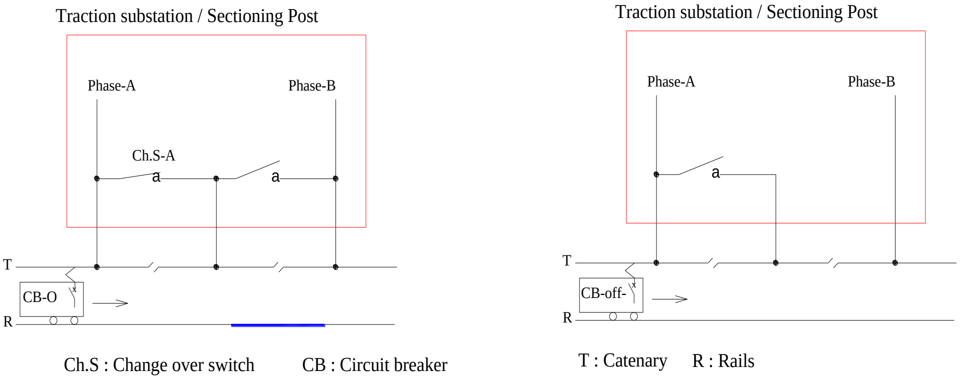

Traction substation / Sectioning Post
Phase-A
Phase-B
Ch.S-A
a
a
T
CB-O
R
Ch.S : Change over switch
CB : Circuit breaker
Traction substation / Sectioning Post
Phase-A
Phase-B
a
T
CB-off-
R
T : Catenary
R : Rails

Figure 10-31: Type of Neutral section provided for High Speed Rails

The PSI side switching method is called the "the changeover section system ". This type of neutral section is adopted in Japanese Shinkansen. In this type of system, the train can pass the neutral section directly during powering or motoring mode. Two types of neutral sections are adopted for on-board CB off method,

1) long neutral section system, which is being used in TGV Paris southeast (PSE) since 1981 is provided in Figure 10-32

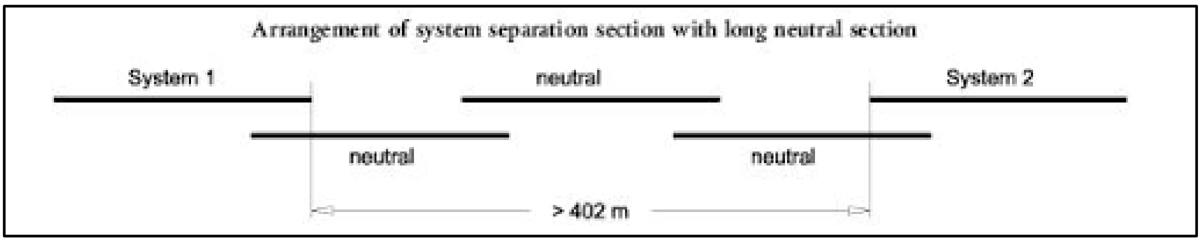

Arrangement of system separation section with long neutral section
System 1
neutral
System 2
neutral
neutral
> 402 m

Figure 10-32: Arrangement of the long neutral section

2) Split neutral section system, this type of split neutral section is used for LGV east in France since 2007 is provided in **Figure 10-33**

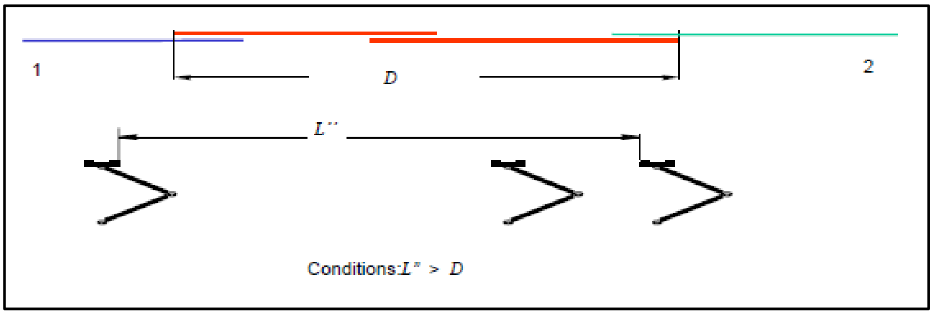


Figure 10-33: Arrangement of the split neutral section

Depending on speed and line characteristics one of the two configurations may be used,

Configuration 1 - D< 142 m, L'' > 142 m

Configuration 2 - D< 79 m, L'' > 79 m

Table 10-27 indicates the type of neutral section adopted in different countries for HSR operation.

Table 10-27 : Type of neutral section provided for High Speed Rails

Type of Neutral section	Countries
Change over section system	Japan and Taiwan
On - board circuit breaker CB off method	France, Korea, UK and Italy

In Japan, the neutral section is automatically power supplied according to the train running position. Usually, when a train goes through a different phase section in front of a substation or a sectioning post, the train would lower the pantographs or keep the notch-off before the section. The HSR train in Japan goes through the change-over section with the notch-on.

In SilverLine, the locations of the neutral section would be middle of the two traction substations and In front of each traction substation. **Figure 10-34** represents the typical arrangement of neutral section and sectioning and paralleling post arrangement in 2x25kV system.

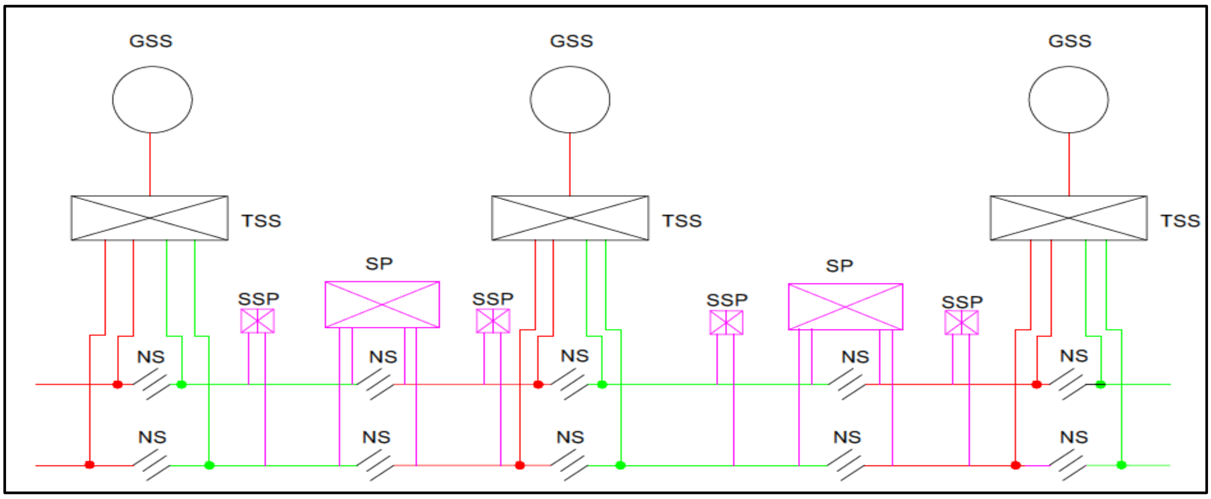


Figure 10-34: Typical arrangement of neutral section and paralleling post

10.10.8 Automatic Tensioning Device (ATDs)

It is used to maintain constant tension automatically and thus maintain good performance for the current collection. In Tokaido Shinkansen, pulley type ATD has been used. In pulley type ATD, there is a need to apply oil to the cable that connects the weight and pulley. In addition, wire breakage due to the aging of the cable also occurs.

Presently, the pulley type ATDs are replaced by spring type ATD in Japan but in India, pulley type ATD's are widely used in Indian railways and metro rails. **Figure 10-35** shows the arrangement of Pulley and Spring type ATD.

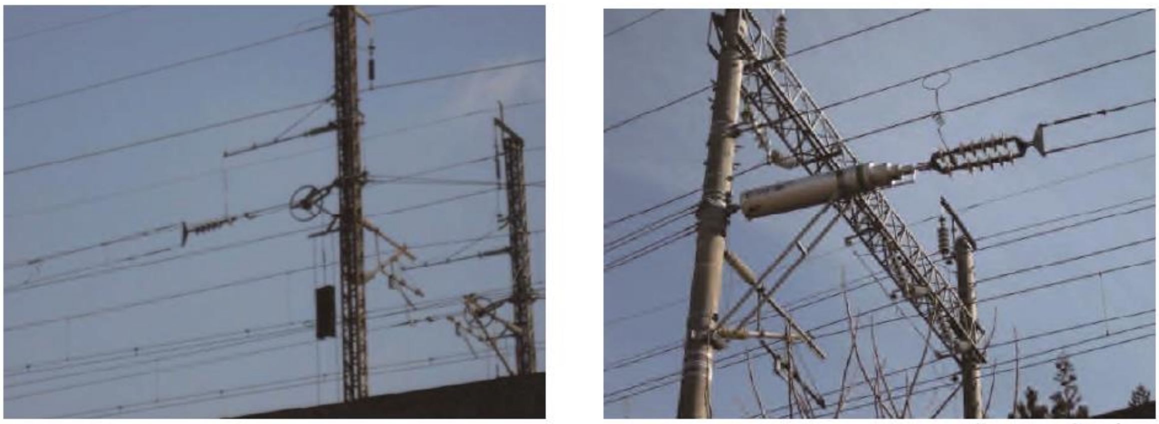


Figure 10-35: Pulley and Spring type ATDs

10.10.9 Electro-magnetic interference Electro-magnetic Compatibility

25kV AC traction currents produce alternating magnetic field that cause voltage to be induced any conductor running along the track. Autotransformer type feeding system is proposed in SilverLine corridor for EMI mitigation. The SilverLine system must comply with the EMC requirement of EN- 50121, EN - 50123, IEC - 61000 etc. Earthing and bonding of traction system shall be in accordance with the latest standards of EN -50122, IEEE-80 and other relevant standards.

10.10.10 Power Line Crossing

The summary of power line crossing for SilverLine corridor is provided in **Table 10-28**

Table 10-28 : Summary of power line crossing

Sr No	Voltage level	Nos
1	220 kV	27
2	110 kV	54
3	66 kV	12
4	33 kV	8
5	11kV	360
6	LT	500
	Total	**961**

The detailed power line crossing of SilverLine corridor is provided in Table 10-31.

10.10.11 Applicable Standard

Table 10-32 refers the applicable standard used for the power supply and traction installation

10.10.12 Earthing and Bonding

Each Traction and Auxiliary substation shall be furnished with a ground mat and provisions for equipment grounding. The grounding system shall be designed so that the step and touch potentials under fault conditions are within the designated limits of IS - 3043, EN - 50179, EN - 50122, IEEE-142, BS-7430, IEC- 61312 and IEEE-80. When earth faults occur in the high voltage supply, the fault current flows through the earthing system. Each substation shall be provided with earth mats of lower resistance and connected to all electrical installation through earth strips. All electrical installations shall be provided with double earthing. The earthing system shall be an integrated system affecting all disciplines (Power supply, signalling, telecom, tunnel ventilation, station utilities, civil works and utility lines in the vicinity or entering the SilverLine)

The earthing and bonding system shall be designed to ensure the following:

a) Ensure the electrical safety (touch and step potential) of the passenger, third parties and staff

b) Protection against lightning strikes

c) To provide means to carry electric currents into the earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affecting the continuity of service

d) Ensure the proper functioning of electrical equipment by minimising electrical interference between electrical systems

e) Provide guidance for establishing protection against electric shock by means of suitable clearances or by the installation of protective barriers or screens

f) Compliance with regulations

The safety technical requirements for earthing are as follows:

- The traction return current causes a voltage rise in the running rails, due to the impedance of the rails, resulting in a voltage between running rails and the surrounding ground or other grounded metallic parts. These voltages need to be limited to acceptable limits
- All equipment used to provide a service to the SilverLine and requiring an electrical supply shall be grounded according to the standards required for current-carrying or non-current carrying parts;

- The grounding and bonding system of the SilverLine AC traction power system shall ensure the safety of persons in case of ground fault occurrence and during the normal operation;
- The additional ground wires which connect the poles of viaduct line sections and the support structures of the tunnel line sections will be connected to the running rails through the centre tap of an autotransformer
- Each substation and auto-transformer stations shall be connected to the running rails by twin return cables. They can carry the whole current after a failure of one of the conductors.
- The dedicated cables are used in viaduct and tunnel sections, they shall be of adequate cross-sectional area and shall be longitudinally interconnected and connected to the running rails. The cable size should be enough to carry the fault current of the traction power;
- The individual earthing systems for bridges, tunnel segments, substations and pole foundations etc shall be connected to the return circuit and form the overall earthing system
- Grounding points must be installed at all specified locations to allow bonding and verification of the electrically continuity and monitoring ground return current and checking the electrical corrosion;
- The grounding of bridges crossing the SilverLine is necessary for the reinforced concrete structures of the bridges. Galvanized flat steel bar, protective corbels and protective fencing shall be connected to the grounding points. If there is a danger of potential transfer, the insulated gaps in the railing should be used;
- To ensure the touch voltage not more than the permissible voltage, the transverse bonding of track at regular intervals should be required;
- For the signalling installations the cable shields along the tracks and the stations must be grounded;
- Protective provisions shall be made for underground metallic pipes and power cable (along-track) against the danger of the stray current of non-railway system;
- For safety, every hand-operated isolated structure shall be equipped with a metallic platform where the operator can stand to operate the device. This platform shall be bonded to the operating handle and the traction ground point;
- The ground wire to the structure ground shall bond emergency escape ladder and deck railings along viaduct;

- Lineside steel fence erected on both sides of the embankment and cutting sections and handrail of the viaduct shall be grounded at the appropriate intervals.

Typical earthing arrangement of stations is provided in **Figure 10-36**

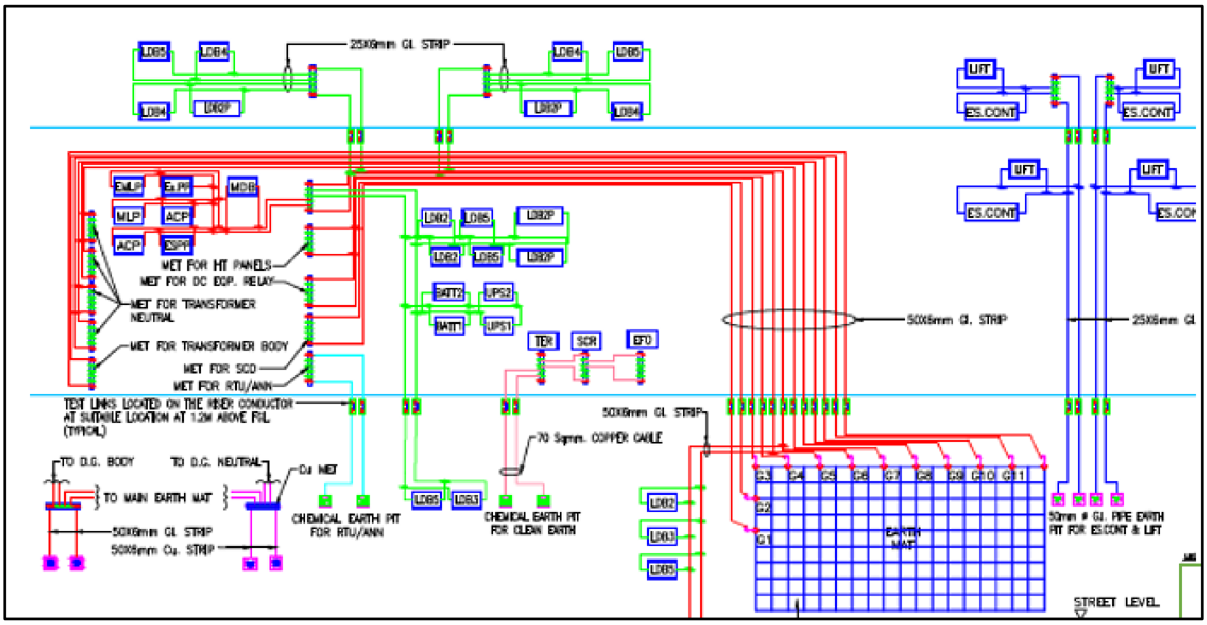


Figure 10-36: Typical earthing arrangement (stations)

10.10.13 Lightning Protection

A lightning protection system shall be provided for large above - ground structures. Each traction and auxiliary facility shall be provided with appropriate lightning protection system conforming to IS -2309, IEC-1024, IEC -62305, IEC 61000-5-2 and BS-6651, EN-50164.

A lightning protection system is required to;

1. Protect an above-ground structure from a direct lightning strike.
2. Protect the equipment housed within the structure and the zone of protection.
3. Protect personnel working within the structure and the zone of protection.

10.10.14 Maintenance of OCS and Traction Substations

To achieve high reliability and zero-defect OCS and Power supply, it is proposed to have the daily, monthly, half- yearly and yearly maintenance of all the system (Power supply installation, OCS and SCADA system)

The OCS is subject to dynamic oscillations due to the constant contact and movement of the fast-moving pantograph coupled with wind pressure. It is necessary to maintain the OCS in perfect condition through proper checks on its geometry and all parameters adopted in the design

I. Maintenance of OCS

The following schedules of maintenance for the OCS are required to be followed to ensure good current collection as well as safety of installations and personnel; -

1. Foot patrolling
2. Trolley Inspection
3. Current collection test
4. Special checks
5. Annual maintenance and OCS inspection car check
6. Re- tensioning of unregulated OCS

II. Maintenance of Traction substation

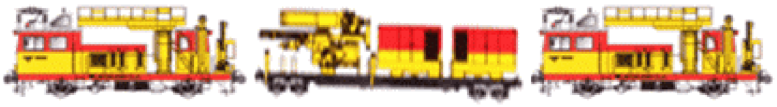
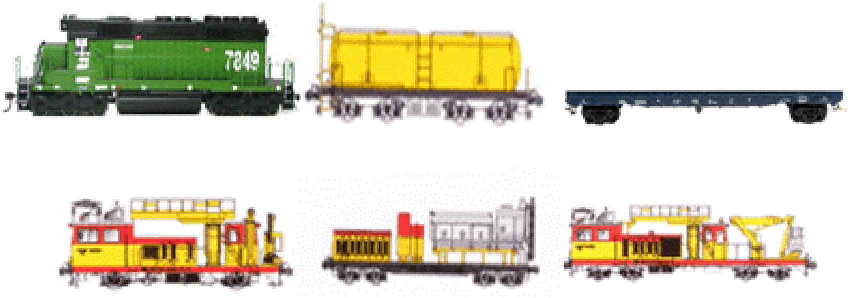
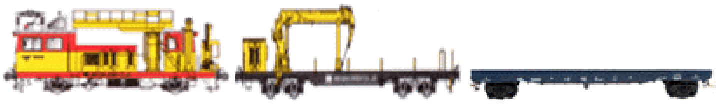
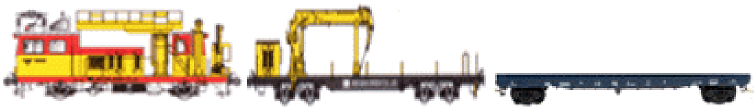
The maintenance schedule of Traction substation is provided in **Table 10-29**

Table 10-29 : Maintenance schedule of Traction Substations

Sr No	Equipment	Yearly	Half yearly	Quarterly	Monthly
1	Lightning arrester	●	●		
2	Current Transformer	●	●		
3	Potential Transformer	●	●	●	
4	Isolator	●	●	●	
5	Circuit Breaker	●	●	●	
6	Power Transformer	●	●	●	●
7	Neutral Grounding Resistor	●	●	●	
8	Control and Relay panel	●	●	●	●
9	Battery and Battery charger	●	●	●	●
10	Earth pit	●	●	●	●
11	Dry type Transformer	●	●	●	●

10.10.15 Construction and Maintenance Vehicle used for High Speed Rail

The construction and maintenance vehicles that can be used for the maintenance and emergency situations on Kerala SilverLine is provided **Figure 10-37**

Process	Vehicle set
Mast base excavation	 Motorcar – Drilling Trolley – Motorcar
Mast base concrete placing	 Locomotive – Material Car – Plate Car, Motorcar – Mixer Car – Motorcar
Mast installation	 Motorcar – Crane Trolley – Plate Car
Support installation	 Motorcar – Crane Trolley – Plate Car
Catenary wiring	 Motorcar – Wiring Car – Plate Car

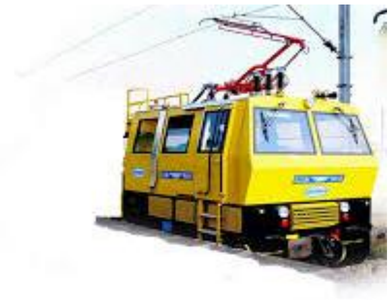
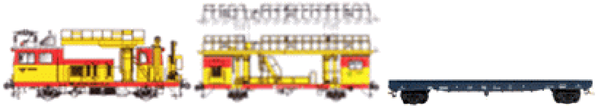
Process	Vehicle set
Tower car	
Contact wire adjustment	 Motorcar – Adjustment Cars (×5) – Plate Car

Figure 10-37: Construction and Maintenance vehicle used for SilverLine

10.10.16 Supervisory Control and Data Acquisition System (SCADA)

SCADA system shall be provided at the operation control centre (OCC) and Back up control centre (BCC) to monitor and control the power supply and traction installations of SilverLine corridor. The control and monitoring system shall be designed to supervise, control and acquire various data from Traction substations, Sectioning and paralleling post (SP), sub sectioning and paralleling post (SSP) and auxiliary substations (ASS) of mainline and depot. A central control station called Operation Control Centre (OCC) and a backup control centre (BCC) shall be provided at Depot. Substation automation System (SAS) shall be provided at Traction substation and Remote terminal unit (RTUs) shall be provided at SP, SSP, stations and depot for controlling and monitoring the High voltage and wayside traction equipment. The communication between OCC to SAS and RTU at control stations shall be achieved through the OFC network.

The SCADA system shall consist of

a. Central control facilities (Servers, Large video wall, workstations, LAN equipment, etc.) at the Operational Control Centre (OCC),

b. A Back-up control centre with similar facilities

For protection, interlock and metering of the equipment, protection control unit (PCU) i.e. Digital Protection Control System (DPCS) shall be installed on all switchgear panels. It shall be able to operate the vital components and work as the interface with the remote SCADA system. The communication between OCC SCADA and the

RTUs/SAS at the power installation ends viz, ASSs, SP and SSP, TSSs and other location, if any, shall be achieved through the OFC network.

It shall be possible to monitor and log the various voltages, currents, power factor, maximum demand, energy consumption and status of various equipment and provide automated control throughout the system at the OCC/BCC through the SCADA system.

The SCADA shall also have provision for plugging in a portable control console (laptop) with the RTU. It shall be possible to operate and monitor the status and alarm conditions of all equipment from this local control console.

Different levels of the communication protocol between TSS, ASS, SP and SSP and the OCC/BCC shall be worked out and necessary liaising/interfacing shall be maintained with telecom contractor to ensure the provision of different levels of communication facilities throughout the system through the OFC.

10.10.16.1 Power Supply Management

The field of activities of the power supply comprises of

1. Power supply management of the Traction substations (TSS), Sectioning and Paralleling post (SP) and Sub sectioning and Paralleling post (SSP) of mainline and depot
2. Auxiliary power supply management
3. Overall energy management

The main functions shall be to visualise the condition of the power supply network , as well as the monitoring panel , to control the pieces of equipment , to inform the operator of any change in the status of power supply network , to indicate several electrical parameters (Energy, power, voltage….) to print a pre-determined log of events and data to store log of events. The traction power supply function shall allow the traction power controller to energize or de-energize the different traction power sections of the line based on demand of the corridor. The controls related to the power supply equipment are performed either from the power workstations or the traction desk or locally from the equipment

10.10.16.2 SCADA Architecture

The SCADA system at Operation Control Centre (OCC) and Backup Control Centre (BCC) shall control the power supply equipment of complete line of SilverLine including Traction substations through Gateway, 25 kV switching stations (SP, SSP and Auxiliary Substations (ASS) through RTU, etc. All software/OS licenses shall be perpetual and shall not be linked with the hardware healthiness of the system. SCADA system shall be provided with Network Management System (NMS) at OCC which enables to monitor all stations RTU network traffic

SCADA system shall be provided with a playback system with enough storage capacity to enable the user to view a recording of the operations performed by TPC during power blocks. All the RTU at the auxiliary substations of Stations and depot, SP and SSP will communicate with main and backup OCC directly through a new redundant network. Substation Automation System (SAS) with local SCADA shall be hooked to OCC from designated gateways.

The SCADA system shall control all RTU and RSS gateways on the line. The control system will include two control servers and enough no. of redundant communications front End (main and Hot stand by), which shall be installed at both OCC's to communicate with RTU at the stations and wayside and Gateway (Traction substations).**Figure 10-38** shows the architecture of SCADA system

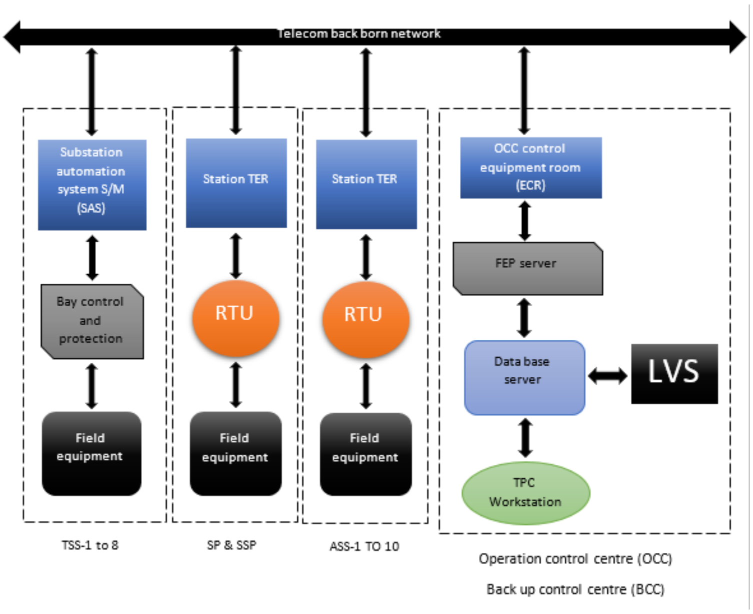

Telecom back born network
Substation automation system S/M (SAS)
Bay control and protection
Field equipment
Station TER
RTU
Field equipment
Station TER
RTU
Field equipment
OCC control equipment room (ECR)
FEP server
Data base server
LVS
TPC Workstation
TSS-1 to 8
SP & SSP
ASS-1 TO 10
Operation control centre (OCC)
Back up control centre (BCC)

Figure 10-38: Typical architecture of SCADA system

10.10.16.3 SCADA Hardware

10.10.16.3.1 SCADA display and access terminal

This terminal shall have access to HMI of all power supply equipment at TSS, SP, SSP and ASS (Mainline and Depot). The operator shall be able to control and monitor the power supply equipment and shall be able to acknowledge related alarms. Power supply equipment related alarms and events will be available in the Alarm viewer & event viewer.

10.10.16.3.2 Large Video Screen (LVS)

LVS display shall be available at OCC. LVS terminal will only be used for displaying entire Power Supply of TSS, SP, SSP, and ASS, of mainline and depot. **Figure 10-39** shows the LVS arrangement in OCC.

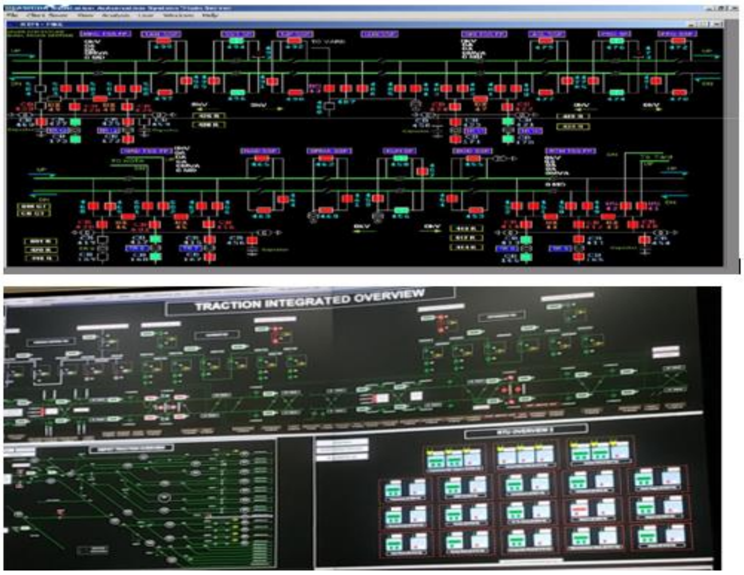


Figure 10-39: LVS display screen in OCC

Using wall Management Software, the operator shall pre-configure various display layouts to be displayed any time with a simple mouse click.

10.10.16.3.3 SCADA UPS

SCADA UPS System providing an uninterrupted power supply to the SCADA equipment installed at OCC.

10.10.16.3.4 Maintenance & Development Work-Station

This terminal shall be used as an engineering workstation for a complete SCADA configuration. Any configuration required for the SCADA system including HMI is to be carried out from this terminal. After execution, the same configuration files shall be deployed in the redundant database server. Remote programming facilities for RTU shall be provided in this terminal. The System Supervision view for the entire communication network shall be available in this terminal. All the system supervision related alarm and events shall also be available in this workstation.

10.10.16.3.5 Portable Terminal

The portable terminal shall be used for RTU Configuration. The Portable system shall be installed with the relevant software of RTU. Once the user connects the portable system through the dedicated port available in the switch at the RTU panel or remotely over the communication network, the configuration for the RTU system can be done.

10.10.16.3.6 SCADA equipment in OCC

The below list shows the equipment available in OCC.

1. Front end /communication server (FEP) with main standby configuration
2. Data base configuration with main and standby configuration
3. SCADA work stations with dual colour monitors
4. Engineering work station with dual colour monitors
5. Large Video Screen
6. Communication Interface equipment
7. UPS and auxiliary feeding distribution
8. Printer
9. Training simulator with Training server and Trainee work stations
10. Training RTU

10.10.16.4 SCADA software

The technical features of the SCADA software shall meet the following minimum technical features:

10.10.16.4.1 Process display

The SCADA software shall support flexible process displays for continuous and effective monitoring at OCC for the Traction & Auxiliary equipment on the power supply network of the K-Rail

The process display feature shall facilitate depiction of Single Line Diagrams (SLD) with a flexible choice of colours for the process objects and backgrounds. The Process displays shall support the zooming and panning facility. The process display features shall be flexible enough to build the complete traction network and the auxiliary network as a single mimic display with the facility to navigate using the mouse from one end of the network to the other. It shall also be possible to zoom portions for a picture for getting a magnified view of the SLD.

10.10.16.4.2 Alarm Management

Alarm Management system to alert operator and maintenance staff during equipment malfunctions or any other system alarms likely to cause disruption to the operation of the SilverLine. The alarm management function shall support

- Two types of alarm list templates (critical and less critical)
- User-friendly filters, Alarm list setting tool for colours and text layout
- Updating/frozen presentation modes
- Alarm acknowledgment, the alarm reset function
- Authorization support

- Help in all dialogs
- Visible alarm Class
- Locate object
- Column sort, find, fields indicating the number of active and unacknowledged alarms
- A field indicating the use of filters
- A field indicating the current presentation mode
- Current/total page number indication on both lists

10.10.16.4.3 Event Logging System

An event logging system for displaying and logging sequence of event recording for the various field inputs configured at the RTU/SAS. The event list contains the following minimum features and options:

- Historical storage of events with the facility to retrieve the same later
- Configurable layout: columns, fonts, toolbars, colouring, and so on.
- Configurable colouring of events
- Configurable scrolling behaviour
- Configurable presentation modes: log/event order, latest at top/bottom
- Updating/frozen presentation modes
- Easy navigation through scrolling, go to date, time filters, and so on.
- Extensive filtering that can be stored and easily called up later
- Find, sorting by column, copy/paste of events to other windows applications
- Printouts
- Commenting of events by the operator

10.10.16.4.4 Measurement Report

The SCADA software shall support the configuration of time-related measurement reports. Measurement Report is used within SCADA's library applications for various types of time-related reports, such as hourly, daily, weekly, monthly and yearly reports. The reports shall be based on time-related follow-ups of process, metered, entered or calculated data. The data for the reports shall be stored in real-time. Report data is collected and calculated cyclically or triggered by events. Periodic backups of reports shall be possible:

The Measurement Reports supports the following time-related reports:

- Hourly report
- Daily report
- Weekly report
- Monthly report
- Yearly report

10.10.16.4.5 Trend

The SCADA shall support trends for performing time-related follow up of process data. The trends shall be possible for both digital as well as analogue parameters. The trends shall be possible in both graphical and tabular forms which shall share the same database. The x-axis and y-axis of the graphs shall be configurable in scale. It shall be possible to have different scan time variable in a single display. The trend display shall support the following features:

- Support of graphical or tabular view modes with zooming facility
- Shall support scrolling with scroll bars and panning
- Configurable axes, line properties, and legend
- Update interval options from 30 seconds to 10 minutes
- Trends for calculation formulas; direct, mean, sum and difference shall be possible
- Shall have printout option
- Depiction of Update/frozen modes
- Facility to copy to clipboard and export to CSV file in a readable format

10.10.16.4.6 Control Function

The SCADA system shall support the control function based on automatic & manual control of power and traction equipment. The manual control of equipment shall be possible using select- check- execute sequence. The open/close function for the operator control action shall be possible to be passed through protective interlock functions.

10.10.16.4.7 Safety tagging

The SCADA software shall support the feature of safety tagging up to at least 2 levels by the addition of note marker. The note marker shall be inserted into any of the pictures and shall be saved even on the condition of change over. The operator shall be able to give some specific instructions to the shift operator using this functionality. Following two signals should be displayed as tag near the breaker symbol:

- L/R status
- MTR status (On clicking this tag MTR should reset)

Reset of the signals should be displayed in the pop-up window.

10.10.16.4.8 Blocking list

The SCADA software shall support feature of blocking list which shall depict the blocking status of update, control, alarm and event for the various database points along with the name of the signal text used in the SCADA system.

10.10.16.4.9 Bus bar colouring

The SCADA software proposed shall support the necessary bus bar colouring feature by which the dynamic status of the bus bar can be depicted during the charged and uncharged condition. The bus bar colouring shall be provided for the Traction overview diagram, Traction individual screens and the ASS overview diagram. The overview diagram shall be provided in the traction power controller workstation and on video wall which acts as a large video screen.

10.10.16.4.10 Technical Requirements

The SCADA system may be based on Linux/MS windows/Unix platform .The system shall have a graphical user interface windows look & feel and shall support the features

10.10.16.4.11 Communication Protocol

The SCADA system at Main and Backup OCC´s shall support the following communication protocols:

- IEC 60870-5-104 for communication between OCC to RSS gateway/ RTU of the line
- It shall also be capable to exchange information with other SCADA systems over IEC 60870-5-104, OPC DA/UA and other standard communication protocols
- All relays shall be synchronized by RTU through Simple Network Time Protocol (SNTP)

10.10.17 Substation Automation System (SAS) in Traction Substation

The substation automation system is commonly used to control, protect and monitor a substation. This system takes data from intelligent electronic devices (IED’s) to control, protect and monitoring the substation equipment.

The Traction substation would be provided with a Sub-station automation system. Dedicated intelligent Electronic devices (Bay Controller IEC 61850 compatible) will be provided in TSS for control, monitoring and protection of various TSS equipment.

Redundant gateway will be provided for control and monitoring from OCC and BCC. Each gateway shall have two communication ports for simultaneously reporting to two masters, to send data of TSS to both OCC´s. The SAS system shall be connected to two control centres on a fiber optic network using two separate channels. SAS should support interoperability. Redundant communication switches and dual optical fiber ring topology shall be provided for interconnecting IED's to SAS panel. SAS Servers shall have a dynamic busbar coloration feature.

10.11 ELECTRICAL AND MECHANICAL SYSTEMS IN SILVERLINE

According to the function and operation requirements of the SilverLine stations and depot, the electrical and mechanical installation shall at least include the following subsystem

- Electrical system
    - LT panels
    - Distribution boards
    - MV cabling and bus ducts
    - Conduit wiring
    - Indoor lighting and fans
    - External lighting
    - Protective earthing
    - Lightning protection
    - UPS system
    - DG set
    - Solar system
- Fire system
    - Fire alarm and annunciation system
    - Fire hydrant system
    - Sprinkler system
    - Portable fire extinguishers
    - Panel flooding system
- Air conditioning and ventilation system
- Elevator
- Escalator

10.11.1 Auxiliary Substation (ASS)

Incoming Supply is received at Main Distribution Board (MDB) through transformers at the Auxiliary Sub Station (ASS) located at the station/Depot building. This power supply is further distributed from MDB to all distribution panels including Sub Main Distribution Boards (SMDB) / Distribution Boards (DB) / Power Distribution Boards

(PDB) etc. The power distribution system provides power to the various electrical loads i.e. Signalling, Telecommunication, Fire pumps, Air conditioning and ventilation, Elevator, Escalator,Water pumps, small power system, lighting system, commercial (property development), etc. **Figure 10-40** shows the 33kV/11kV HT panel, Transformer and Main Distribution Board arrangement in the Auxiliary substation

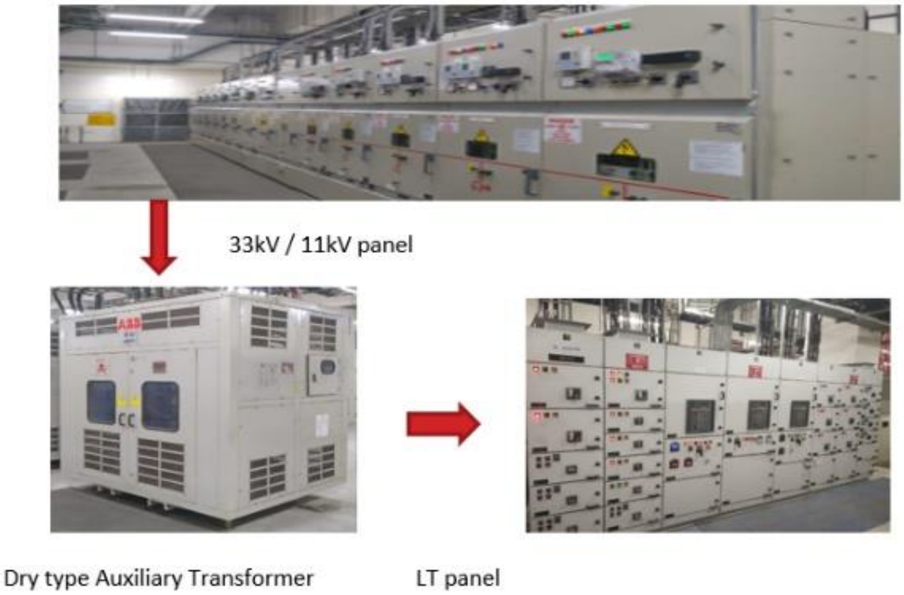


Figure 10-40: Equipment arrangement in ASS

Each auxiliary substation will house the following equipment:

a) HV Panel for incoming 33kV/11kV supply

b) Transformer

c) Main Distribution panel and Sub distribution panels

d) Station UPS comprising battery bank

10.11.2 LT Panels/Distribution Boards

All medium voltage switchboards shall be suitable for operation at three-phase/three phases 4 wire, 415-volt, 50 Hz, a neutral grounded system with a symmetrical short circuit level. All panels/boards shall be front operated, dust, vermin proof, extensible, top/bottom cable entry, compartmentalized with lockable hinged doors. The maximum overall height of panels and the maximum/minimum height of the operating handles from floor level shall be as per standard norms. Ventilating louvers where required shall be provided on the sides of the panels and shall be of the approved design to suit local conditions.

The arrangement of Main Distribution Boards at station and Depot is provided in **Figure 10-41** .

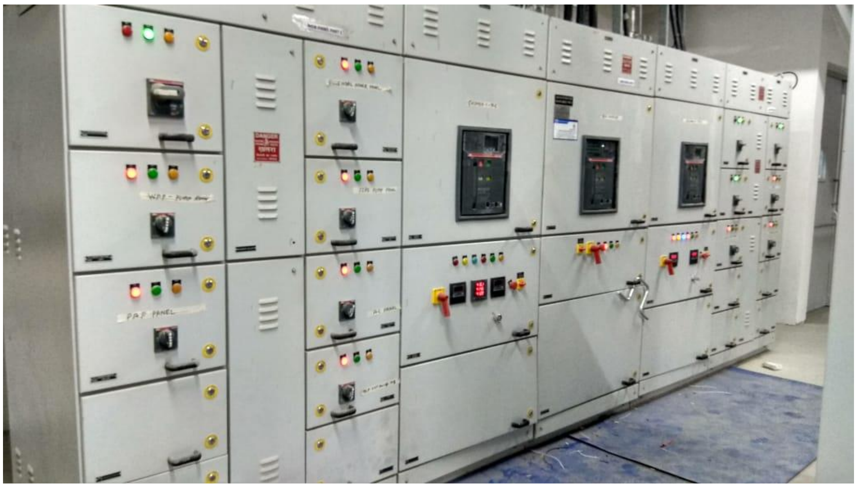


Figure 10-41: Main Distribution Board (MDB) arrangement in Stations and Depot

All LT panels shall include the following:

- Multifunction meter, Power Factor and Energy Meter for each incomer on the main distribution board.
- Main switchboards of suitable communication interface will be provided for connectivity of SCADA/ BMS from all metering which needs to supervise from OCC.
- Multiple LED type indicating lamps shall be provided for indication of phases and breaker position ‘OFF’, or ‘ON’
- All relays, meters & switches shall be flush mounted.
- All metering equipment shall be the digital type

All LV panels shall be constructed in accordance with the requirements of IEC 60439-1&2,8623-1&2, IEC -62262, IEC -60439-1, BS 1432, EN /IEC 60255 and the latest RDSO guideline

10.11.2.1 Single line diagram of Typical LT panels

Figure 10-42, Figure 10-43 and Figure 10-44 represent the arrangements of auxiliary feeding of SilverLine stations. The various distribution panels used in SilverLine stations are Main distribution panel, Essential panel, Emergency panel, Fire pump panel, Water pump panel, AC power panel, Escalator panel, Passenger amenity panel etc

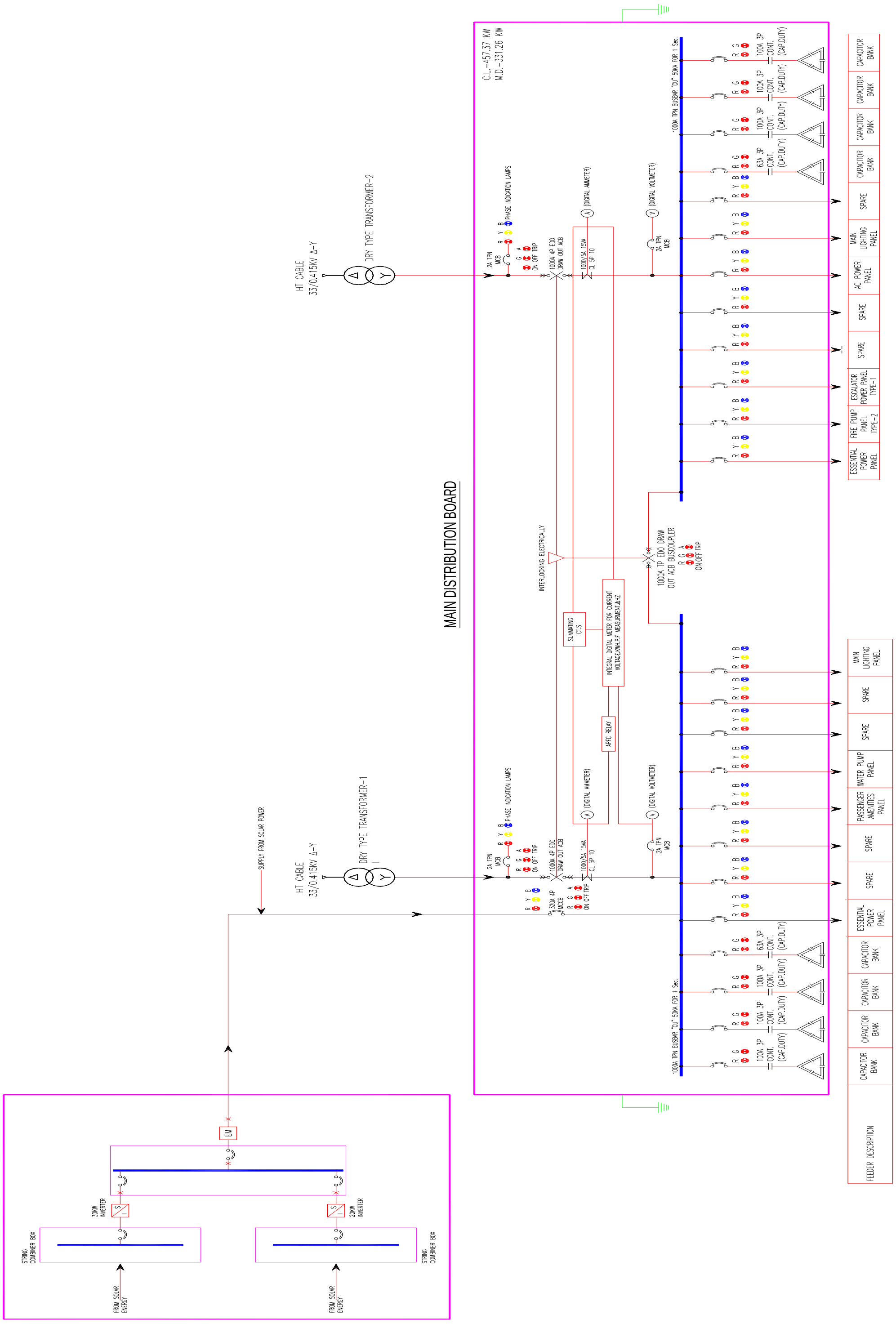


Figure 10-42: Typical Single line diagram of Main distribution board

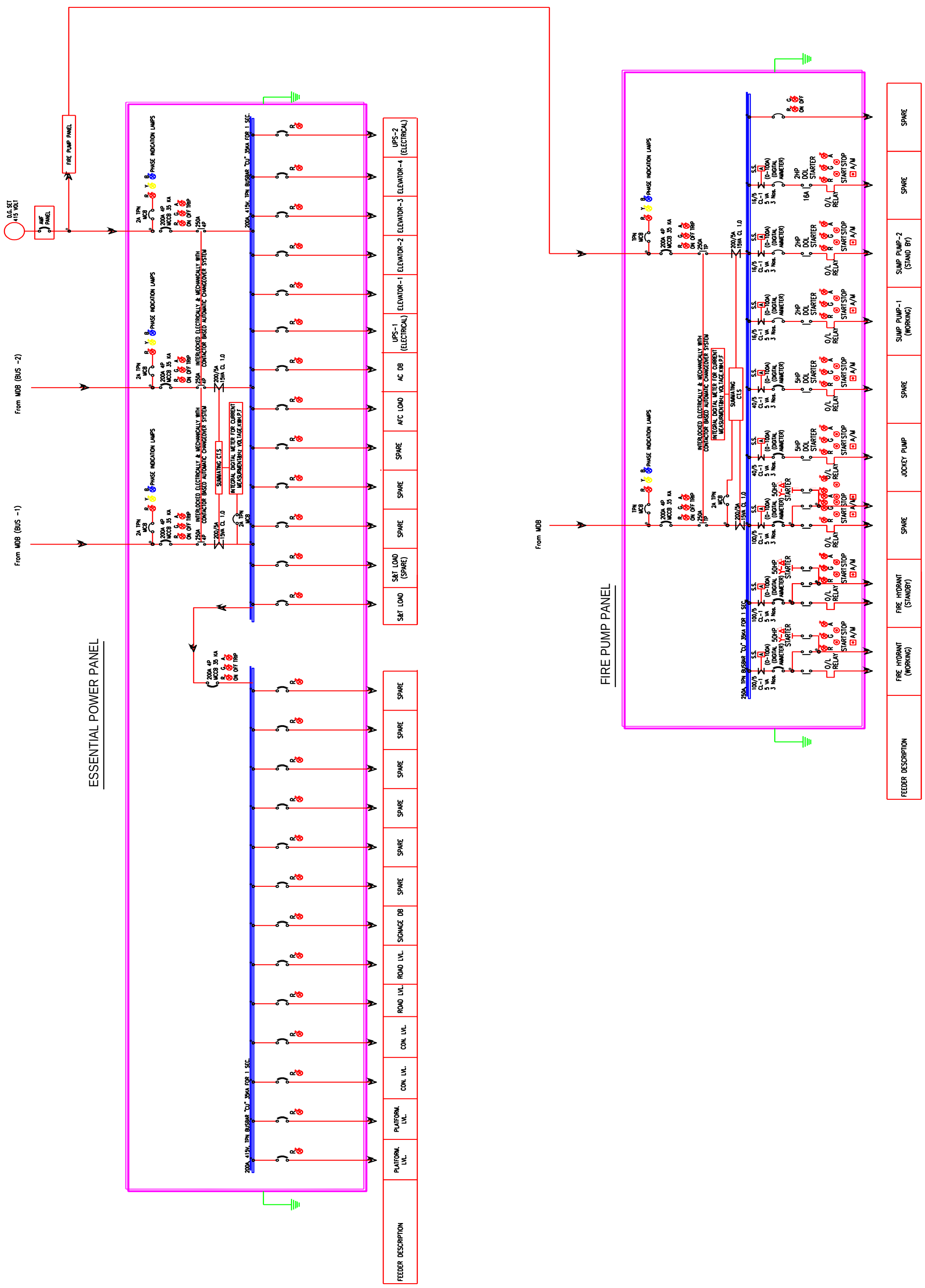


Figure 10-43: Typical Single line diagram of Essential and Fire pump panel

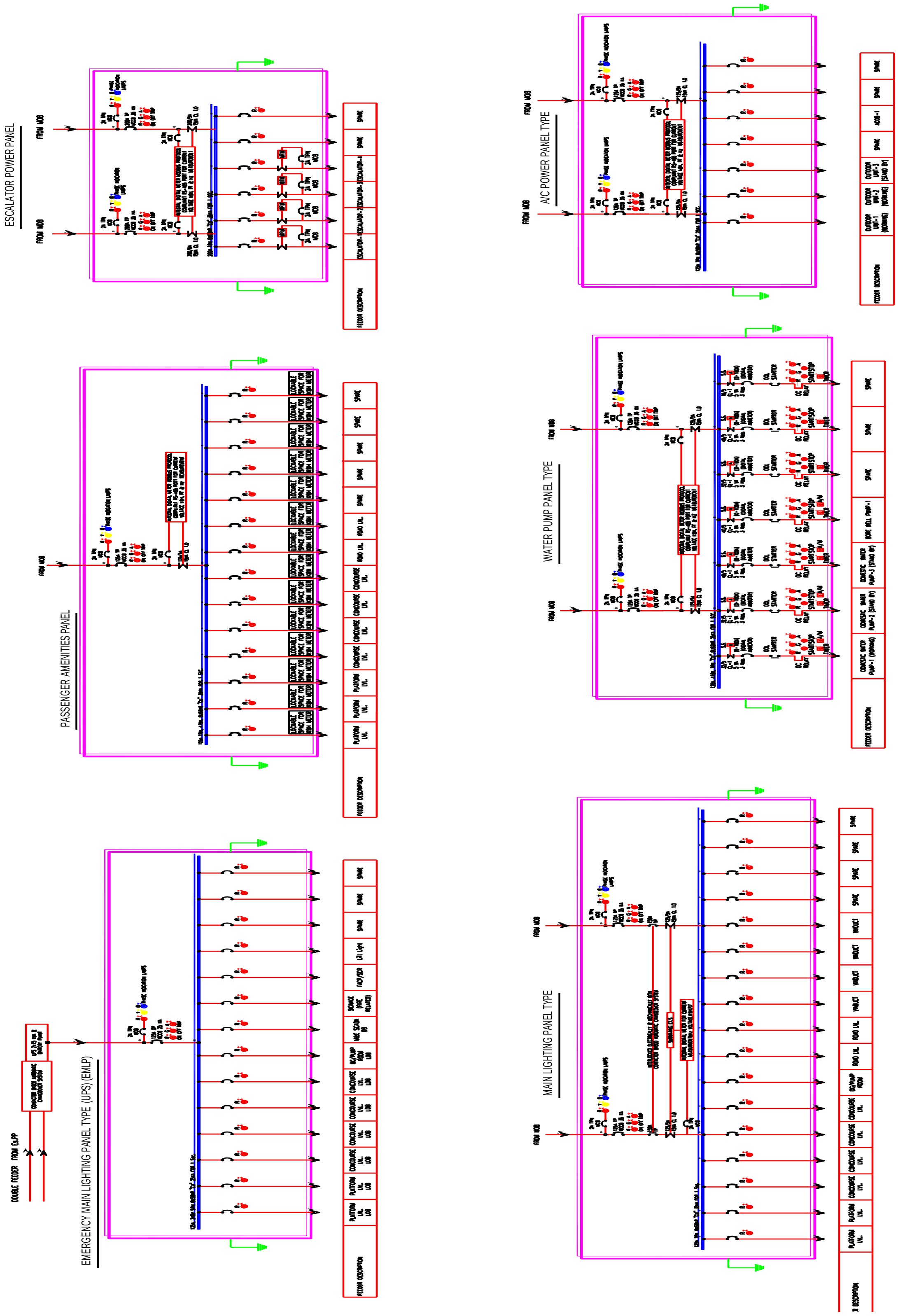


Figure 10-44:Typical Single line diagram

10.11.3 Lighting System

Lighting system shall be installed throughout all stations areas, depot areas, tunnel ancillary buildings, parking areas, auto/taxi bus drop off points and relocated / new access roads. The lighting shall be designed to achieve a bright look, avoid any dark patches, and afford easy and safe access to all other areas. The lighting shall be enough to avoid an unsafe situation under any normal or abnormal conditions. All station premises shall have adequate lighting, including foot-bridges and under passages, stairways, steps, ramps, escalators, equipment room, etc during operation and maintenance time. The illumination level in stations shall satisfy comfort level and safety to the commuters. The height of lighting fixtures shall be adequate to provide effective illumination and thus enable passengers and staff to have a good visual view.The number of luminaires shall be calculated based on the lux level calculation (using Dialux or any other lighting software) to achieve the required illumination level and uniformity. Various types of luminaires will be used depending upon usage, the height of the area and hazards present in the room.

Following points shall be considered for the selection/design of indoor /outdoor light fittings

- All lighting fixture shall be LED type to reduce the energy consumption
- All fixtures shall be complete with accessories and fixings necessary for installation.
- Fixture housing, frame or canopy shall provide a suitable cover for the fixture outlet box or fixture opening.
- Fixtures and/or fixture outlet boxes shall be provided with hangers to adequately support the complete weight of the fixture tightly secured to a fixture stud in the outlet box.
- Lighting for stairs and escalators shall be designed to emphasize illumination on the top and bottom steps and landings.

Lighting system requirements associated with electrical systems and equipment shall comply with the relevant latest version of the requirements of IS-3646(all 3 parts), IS-1913, IS-1777, IS-374, IS-10322(ALL parts), BS-5266, BS-5489,BS-8206,BS/EN 60598,IEC-60598,IEC -62031, LM -79, NFPA -130, NFPA -101, National Building code 2010 and the latest RDSO guideline . **Figure 10-45** shows the typical lighting arrangement for HSR stations.

Figure 10-45: Lighting arrangement for HSR stations

10.11.4 Emergency Lighting System

Emergency lighting system shall be installed to ensure that all the escape routes, including tunnels, trainway, walkway, from the various areas, shall be safely and effectively identified in an emergency. Emergency lighting shall be supplied from UPS, designed to meet the requirements of illumination.

The safety technical requirements for emergency lighting are as follows:

- Emergency lighting shall be in accordance with the firefighting Code and building code (NFPA 130, NFPA 101, NFPA 70, NBC latest etc).
- Emergency lights shall be installed in all areas of the station. The emergency illumination shall provide the following features;
  - At least 25% of the illumination provided by emergency light fixtures.
  - Emergency light fixtures at critical locations along the exit direction inside the station should be used as escape lights. They should be equipped with batteries.

10.11.5 Un-interrupted Power Supply

Un-interrupted power supply system (UPS) is required to ensure that there is no total darkness at the station under any circumstances. Following points shall be considered for the selection of UPS

- The UPS shall be a true parallel redundant, online input 3-phase 415 V & output 1-ph 230 V complete with all modules like converter, inverter, bypass modules with battery backup with charging arrangement and other standard accessories.
- UPS shall be provided with suitable communication interface for remote monitoring from Operation Control Centre.

Following minimum subsystems shall be connected form emergency supply

- Emergency lighting
- Emergency signage
- Elevator lighting and fan
- Public Announcement (PA)system
- Fire command centre
- Gas flooding system in electric panels
- Protective signalling system

10.11.6 Diesel Generator Set

A DG set of suitable capacity shall provide the back-up power to emergency & essential categories of loads. The starting of DG set shall be controlled through an automatic mains failure panel (AMF). The supply from the DG set shall be received at LV switchboard provided in ASS and the DG set supply shall be extended to essential Power Panel (EPP). The generator set shall be able to start automatically even in cold conditions and shall take full rated load within predefined time of failure of the normal supply through an automatic changeover switch. **Figure 10-46** shows the arrangement of a DG set in the DG room of stations.

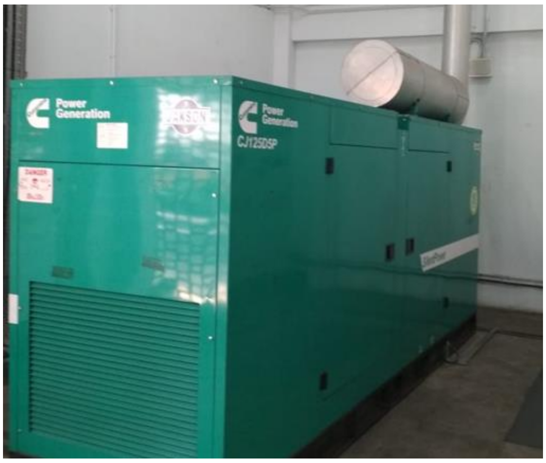


Figure 10-46: DG room

All DG sets in accordance with the requirements of BS-5514, BS-649, IS-4722, IS-8183, BS-4552, BS-7226, IS-3043, ISO -8528, NFPA -130, Latest CPCB norms for noise level, Height of stack/chimney and emission levels, National Building code 2010 and the latest RDSO guideline

10.11.7 Air Conditioning System

24-hour air conditioning shall be provided to critical equipment rooms such as signalling, and telecommunications. The air conditioning system shall be designed in such a way to maintain the required temperature and humidity in the equipment and operational room. The following rooms of the stations and Depot will be generally airconditioned

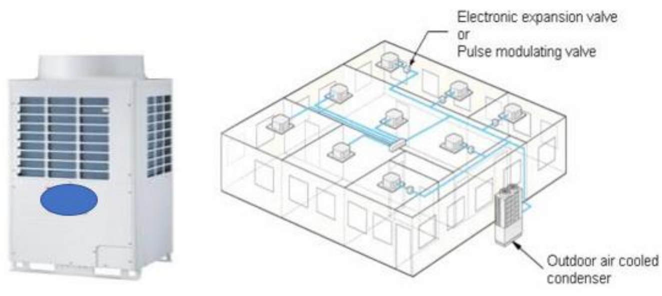
- Station
  - Station Control Room
  - Ticket office Room
  - Excess fare Control Room
  - Signal maintenance Room
  - Telecom maintenance Room
  - UPS room
- Depot
  - Operation Control Centre
  - All S&T equipment room
  - All electronic lab
  - Training rooms
  - Office room

To achieve the above stated inside conditions, it is proposed to use the Variable refrigerant volume (VRV)/Variable refrigerant flow (VRF) air conditioning system and five star rated split type AC system into Stations and Depot.

Heat load calculation shall be prepared to select the appropriate refrigeration capacity of air conditioners for various rooms. The air-conditioning system shall be in accordance with the requirements of ASHRAE /ISHRAE standard.

10.11.7.1 VRF /VRV System

The Variable Refrigerant Volume VRV / Variable Refrigerant Flow VRF- R-410A refrigerant system should be air-cooled, air conditioning systems shall be consisting of modular condensing units connected to multiple indoor units, each having the capability of individual setpoint control. **Figure 10-47** shows the VRF arrangement in Station and Depot.



VRF – Outdoor unit

VRF – Outdoor unit and Indoor unit

Figure 10-47: VRF outdoor and Indoor arrangement

The indoor units shall be provided with corded remote control as a standard accessory. The VRV / VRF units shall be capable of operating within a wide range of ambient temperatures.

10.11.7.2 Split Air conditioners

The split Air conditioner system with a 5-star rating shall be provided if required.

10.11.7.3 Panel mounted Air conditioners

Panel mounted air conditioner may be provided to cool only the panel and not the entire room, wherever possible.

10.11.8 Building Management Systems (BMS)

The Building Management System consolidates the monitoring and control functions of all auxiliary subsystems in common operation terminal, providing a user platform that can be operated through an integrated human–machine interface (HMI). The building management system consolidates all information and control of the electromechanical equipment of Station, Depot and Tunnel. All electrical equipment will be provided with monitoring facilities for interconnection to the BMS system. The main components shall be

- The BMS system must handle all the monitoring and control of electromechanical equipment in each Station, Depot and Tunnel.
- The BMS shall be integrated with Fire Alarm System (FAS) at stations, for detection and notification of fire conditions in the station area.
- The BMS system at the Operation Control Centre (OCC) provides overall monitoring of all the stations along the corridor.
- The BMS shall perform the control, monitoring and supervision of Tunnel ventilation systems, Air Conditioning System, Low Voltage Power & Distribution System, Fire Alarm System, Hydraulic System (Seepage, Sewage, Bore Well Pumps etc.), and other nominated Building Services (escalators, elevators).

- The BMS shall help in energy conservation, planning and executing various energy conservation control schemes.
- The architecture of a typical BMS system is provided in **Figure 10-48**

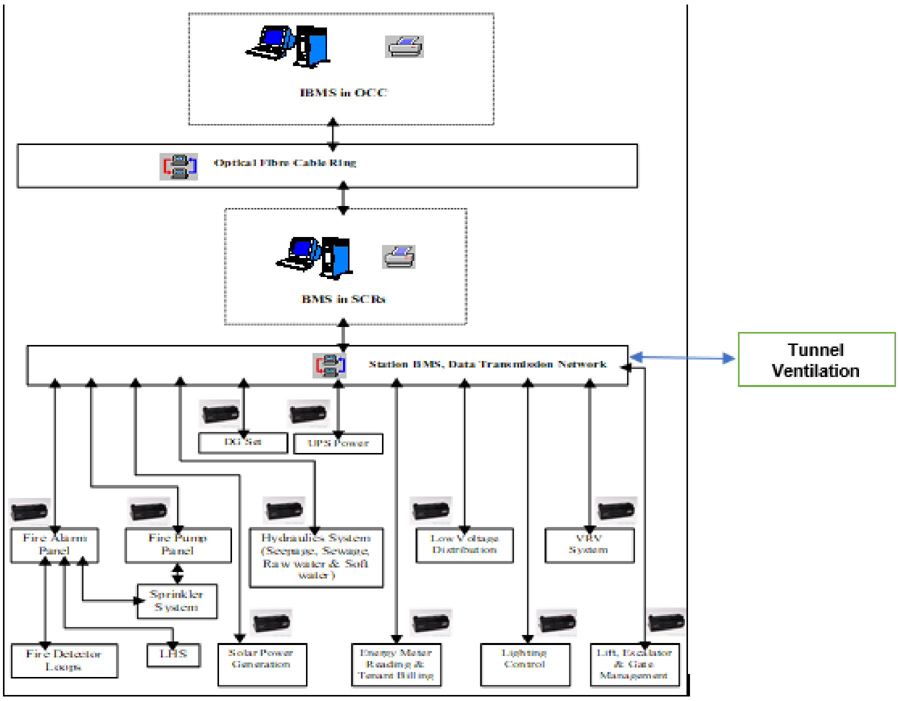


Figure 10-48: Architecture of Building Management System (BMS)

10.11.9 Fire Alarm and Detection System

The fire detection and suppression system shall consist of fire control panels, fire detectors, and suppression monitoring devices.

Fire alarms, fire alarm control panel and associated fire detector device status, fire suppression system equipment status, and suppression system alarms shall be enunciated at central control.

NFPA 130 shall be used as the guiding standard for the fire detection and alarm system. The system shall be designed in an integrated manner in accordance with NFPA-72D, BS-5839, BS/EN-54, ISO-7240, as appropriate or other Internationally recognized or local code. The requirements of the Kerala Fire Service Department shall be incorporated into the system.

Fire Detection System: The fire detection system for each station, depot building, and other structure shall include but not limited to;

- Fire Alarm Panels
- Manual Call Points
- Fire Detectors (smoke/ heat)

- Audible Alarms

10.11.9.1 Fire alarm and repeater Panel

The fire alarm panel shall be provided at the station controller room and the repeater panel can be placed at the security control room. **Figure 10-49** shows the fire alarm panel.

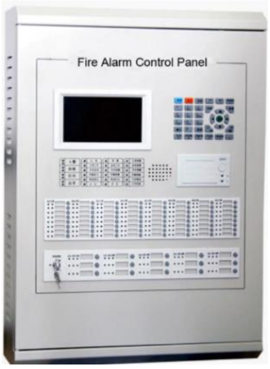


Figure 10-49: Fire alarm control panel

10.11.9.2 Smoke Detectors

The optical detector shall work on a light scattering principle and capable of responding to any heavy smoke particles. The detector shall have LED at the base to indicate visually in case of a fire. **Figure 10-50** shows the smoke detector arrangement.

Figure 10-50: Smoke detector

10.11.9.3 Heat detector

Heat detector shall be thermistor type, working on rate of rising and fixed temperature principle. The detector shall be suitably protected against dust accumulation/ingress and it shall be free from maintenance and functional test at intervals. **Figure 10-51** shows the heat detector arrangement.

Figure 10-51: Heat detector

10.11.9.4 Manual Call Boxes

Manual call points shall consist of a push-button switch housed in a dust-tight sheet steel enclosure to manually initiate audio-visual alarms. The front shall be sealed with a breakable glass cover fixed in such a way that the actuating push button is kept depressed if the glass is intact and released automatically when the glass is broken. **Figure 10-52** shows the manual call box arrangement.

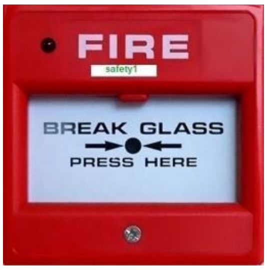


Figure 10-52: Manual call Box

10.11.9.5 Hooter cum Speaker

Hooter cum speaker will be provided in operational area, Service areas and exit areas in public spaces near Hose Reel Stations. Dual Tone hooter shall be of an electronic type and shall give discontinuous/intermittent audible alarm automatically whenever a smoke detector or heat detector operates. The hooter should also have facilities for speaker announcement. Hooter should also have the capability of adjusting the sound output. **Figure 10-53** shows the hooter cum speaker arrangement.

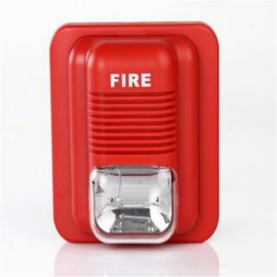


Figure 10-53: Hooter cum Speaker

10.11.9.6 Response Indicator

The Response Indicator shall glow clearly in case the detector to which it is connected gives an alarm signal. There shall be two numbers of red LEDs to compensate for fusing of either LED. **Figure 10-54** shows the response indicator arrangement.

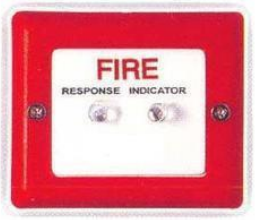


Figure 10-54: Response Indicator

10.11.9.7 Public Address and Voice Alarm System

An emergency voice alarm system shall be installed to meet the requirements of the following standards, BS 5839-9:2003, BS 5839-8:2008, BS EN 54-24:2008, BS EN 60849, BS EN 54-3:2001 Annex C, BS EN 54-16:2008.

10.11.10 Firefighting System

The firefighting system shall include the following subsystems

a. Wet Main system
b. Fire hose reel system
c. Automatic fire sprinkler system
d. Automatic Clean gas total flooding system or Panel Flooding System
e. Portable fire extinguishers

The hydrant system shall manually operate a firefighting facility. In the event of a fire, the fire hoses are coupled to hydrant valves through the instantaneous couplings and the jet of water is directed towards the seat of the fire. When water is discharged through hydrant valves header pressure falls and hydrant pumps are started automatically through pressure switches.

10.11.10.1 Wet main system

The wet main system shall comprise fire service breeching inlets, fire pump sets, water tank with level switches, all necessary valves, pipework, hydrants, hose reels, pump motors with starter panels and all controls. The design, supply, and installation of Wet mains system shall be based on National Building code, BS-9990 & BS-9999 and NFPA -14/20. The hydrant system will cover the station buildings and areas through underground/over ground pipework hydrant pumps. The hydrant system in street level shall be provided with external hydrants. External hydrants shall be furnished with instantaneous couplings and instantaneous pattern branch pipes. Hoses, branch pipes, and nozzles for external hydrants will be stored in hose boxes near external hydrants. Hydrant risers will be provided for the storied station with landing valves at each landing. All risers shall terminate at the highest point with an air release valve. Hose boxes complete with hoses branch pipes and nozzles shall be provided alongside landing valves.

10.11.10.2 Fire water pumping system

The fire pump shall be started automatically on loss of pressure. Two numbers of AC electric motor driven fire pump for the hydrant system (one working and one standby) shall be provided, which shall cater to the water requirements of the firefighting system. The complete piping network for the hydrant system will be kept pressurized. To cater to minor system leakages and to maintain system pressures a pressurization system consisting of 1 no. Jockey pump shall be provided. These pumps will be in the fire pump room. Pumps of the hydrant system are sized confirming to NFPA-14 and National Building Code (NBC). Arrangement of fire pumps in the pump room is provided in **Figure 10-55**.

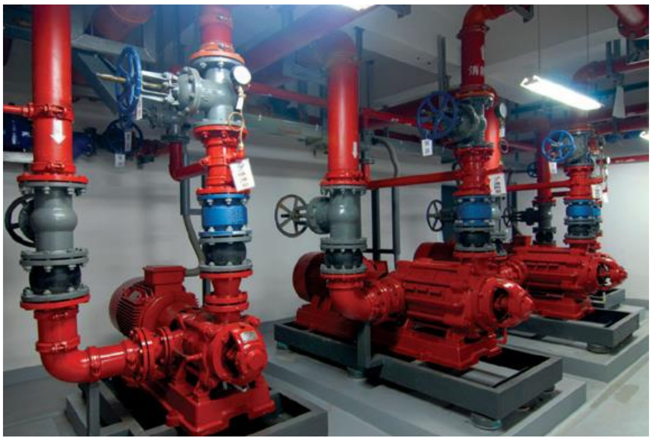


Figure 10-55: Arrangement of Main, standby and Jockey pumps in pump room

10.11.10.3 Hose Reels

Fire Hose Cabinet (FHC) with hose reels shall be provided within the stations and depot to ensure that all floor areas within the stations /depot are reachable by the water jet. The provision and installation of the fire-fighting hose reels shall be in accordance with NFPA 130, BS EN 671-1, BS 5306-1, BS 5306-3, BS 5306-8, and BS EN 3-7 and National Building Code. **Figure 10-56** shows the hose reel arrangement in stations.

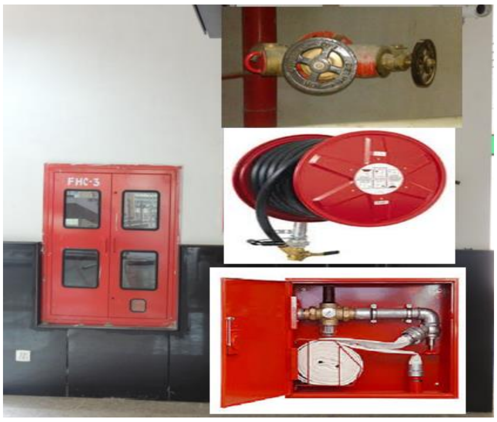


Figure 10-56: Arrangement of FHC in stations and Depot

10.11.10.4 Automatic fire sprinkler system

An automatic sprinkler system shall be installed in each station/depot and shall comprise of fire service inlets, pump sets, pump controls, sprinkler heads, pipework, and associated valves, flow-switches, pressure switches, water motor alarm gong, the water tank, and level switches. The sprinkler system shall be designed as per NFPA16/ BS EN12845. In the event of fire in rooms, the sprinkler heads in the area of fire should sense the high temperature and should burst and discharge water on to the affected area.

10.11.10.5 Portable Fire Extinguishers

All the areas of the station/depot shall be protected with portable Fire Extinguishers in accordance with the requirements of NFPA-10 and NBC. Fire extinguishers shall be provided and installed as per BS EN 3-8:2006, BS 5306-3:2009 Code of practice for fire extinguishing installations and equipment on premises - Commissioning and maintenance of portable fire extinguishers; and BS 5306-8:2000 Code of practice for fire extinguishing installations and equipment on premises; Selection and installation of portable fire extinguishers. **Figure 10-57** shows the fire extinguisher arrangement in stations.

Figure 10-57: Portable fire extinguishers

10.11.10.6 Automatic Clean Gas Protection

All automatic clean gas suppression systems shall be installed to BS EN 15004 & BS EN 10294 and fully integrated into the main alarm panel. A combination of total flood or localized panel flood systems shall be employed within the following areas; transformers, switchgear, UPS and DC Battery System, signalling and communications equipment rooms.

10.12 ELEVATOR

SilverLine Rail System shall be equipped with machine-room less elevators for passengers including specially-abled and elderly persons in Stations. Most of the elevators will be with two landings. The installation of elevator in accordance with the requirements of IS-14665, IS-15785, IS-15330, IS-7759, IS-1860, EN-81, BS-5655, Guidelines and space standard for disables and elderly persons by CPWD, NFPA -

130, National Building code 2010 and the latest RDSO guideline. **Figure 10-58** shows the Elevator arrangement in HSR stations.

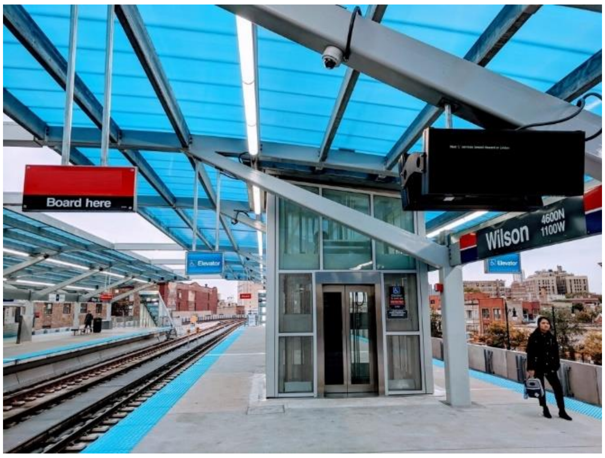


Figure 10-58: Elevator arrangement in HSR Station

All elevators shall be provided with the following minimum features:

- Elevator control buttons at locations and height specified in IS 15330. Hall call buttons at locations and height specified in IS 15330.
- Handrails, straight through type, having minimum 3 supports, shall be provided on the sidewalls of the elevator at height & locations specified in IS: 15330. Symbol of access to the specially-abled shall be permanently displayed at each elevator landing next to the elevator entrance. Braille notations indicating the floor levels shall be incorporated next to each button at the car operating panel and handicap hall call buttons.
- A digital voice system for announcing the car position, opening/closing of doors, direction of travel and messages shall be provided as per IS: 15330.
- A laminated framed safety mirror of at least half of the size shall be installed on the rear panel of elevators at the appropriate position. To facilitate the easy reversal/ exit of the person in the wheelchair from the elevator without the need of rotating the wheelchair in the elevator.
- The design of the elevators shall take into consideration fire prevention, elimination of dust and dirt traps, and easy accessibility for cleaning and routine maintenance.
- A gearless motor having VVVF control and braking technology shall be used in machine room-less elevator
- Illumination of cars and lighting fixtures

  LED type light fixture shall be used inside lift car and lift shaft for illumination. The minimum illumination level at the floor of the elevator car shall be minimum 150 lux.
- Emergency lighting

A maintenance-free emergency light fitting shall be provided in each elevator car and shall illuminate immediately and automatically in the event of failure of the normal car lighting electrical supply.

- Elevator functions
  The following functions shall be incorporated in elevators
    - Door Nudging Feature
    - Next Landing
    - Door load Detector
    - Safety Door Edge
    - Overload Holding Stop
    - Electronic Door Safety
    - Homing Service

10.12.1 Operating and Safety Devices

The following minimum safety devices shall be included in the elevators

- Each elevator shall be provided with an overload device, which shall operate when the load in the car exceeds the rated load. When activated, this device shall prevent any movement of the elevator car and shall cause a warning buzzer on the car to be set off and illuminate an “Overload” signal. This device shall be incorporated in the car operating panel.
- The water sensors in the elevator pits shall be provided wherever pits are on the ground level or below the ground level. Water sump shall be provided to the elevators if the elevator starts from the ground floor.
- An inspection control panel shall be fitted on the top of the elevator car for maintenance purposes.
- An automatic re-levelling device shall be provided which returns the elevator to the floor automatically.
- An over speed governor shall be provided, which can activate the safety gear in the event of the elevator exceeding the rated speed by 40%. The governor shall be adjusted to operate the safety gear following the recommended limits set out in IS-14665.
- A phase protection device and 3 phases, as well as a single-phase earth leakage protection device shall be provided in the main control cubicle of each elevator
- In the event of failure of the normal electrical supply, the supply to the alarm cum intercom system, emergency car lighting, and the ventilation fan shall be automatically switched to an emergency battery operated power supply (UPS).
- Two switches shall be provided in the elevator shaft, one at bottom landing and other in the pit which, when in the “STOP” position, shall prevent any movement of the elevator car, including inspection/ test operation, until both the switches

are set to the "RUN" position. The switching positions shall be prominently labelled.

10.12.2 Provision of Remote Monitoring System (RMS)

The remote monitoring system may be provided to elevators to monitor the following minimum status;

a. Provision of elevator fault/trip signal

b. Provision of elevator car alarm signal

c. Provision of power available and failure status

d. Provision of the elevator under maintenance signal

e. Receiving remote control signal for parking on/off operation

10.12.3 The Special Emergency Operation For Elevators

The elevator operation system shall be designed to provide the following minimum emergency operation.

- **Emergency operation of elevators in the event of power failure**: In the event of power failure or power interruption or single phasing or unbalanced phases, the supply to all elevators shall be automatically switched over to the emergency power supply ie. to Automatic Rescue Device (ARD) and the elevators shall be brought to the designated floor and shall park there with the doors remaining open. In case power supply to the elevator is restored through DG set before the elevator reaches designated floor even then ARD should complete its function and elevator doors should open at the designation floor to evacuate the passenger.

- **Emergency operation of elevators in the event of fire:** In the event of fire or when any fire detection device is activated, all elevators shall automatically be brought to the designated floor (Ground Floor in case of Ground to concourse Elevator and to Concourse in case of Concourse to Platform Elevator or as per requirement of K-Rail) and shall park there with the doors open for 15-20 seconds and then close. The essential buttons such as "Door Open", intercom and alarm bell, etc on the car operating panels shall remain functional and illuminated.

10.13 ESCALATOR

Escalators shall be heavy-duty type, energy efficient with VVVF (Variable voltage variable frequency) drive, reversible type and capable of operating safely, smoothly and continuously in both directions. The installation of the escalator following the requirements of EN-115 and IS 4591. **Figure 10-59** shows the Escalator arrangement in HSR stations.

Figure 10-59: Escalator arrangement in stations

- Escalators shall be designed for installation and operation at an angle of inclination of 30°.
- Heavy-duty escalators shall be self-contained units consisting of truss, tracks, step drive units, steps, step chains, comb plates, handrails, landing plates, driving machines, controllers, safety devices, balustrades and all other components required to provide a complete installation. Materials used shall be non-combustible and selected to achieve a fire-resistant installation.
- Escalator design shall consider fire prevention, elimination of dust and oil trapping configurations, ease of handling, access into the station and easy accessibility for routine maintenance.
- Escalator components shall be protected against corrosion.

10.13.1 Operating and Safety Devices

Operating and safety devices conforming to the following minimum requirements shall be provided:

- Starting Switch
- Service Stop Switch
- Emergency Stop Switch
- Speed Governor
- Broken step Chain Safety Device
- Broken Drive Device
- Non-Reversing Device
- Handrail Finger Guard Safety Device
- Step and Skirt Safety Devices
- Comb plate Safety Device
- Step Lowering Device
- Normal Stop Switch
- Inspection Control
- Missing step detection device
- Handrail Speed Detection Device
- Broken Handrail Device
- Floor Plate Safety Device
- Step Up-thrust Device
- Dress Guard
- Brake Lining Safety Switch
- Phase Protection Device
- Motor Overload Device
- Earth Leakage Protective Device

10.14 TUNNEL VENTILATION SYSTEM (TVS)

10.14.1 Tunnel Configuration

HSR tunnel configuration are commonly

- **Single bore double track Tunnels (Japan, Taiwan and shorter tunnels in Spain): Figure 10-60** shows the arrangement of single bore double track tunnels. This kind of tunnel houses two parallel tracks within one large-diameter tunnel. In this type of arrangement, points of egress for rail users are provided at tunnel portals, the intervention of shafts and opening formed in a central partition wall, if utilized Single bore double track tunnels have the advantage of a larger tunnel area to reduce the impact of shock waves. Separate egress tunnels or intervention shafts to the surface are required and they need more air to be moved to achieve critical velocity during an emergency.

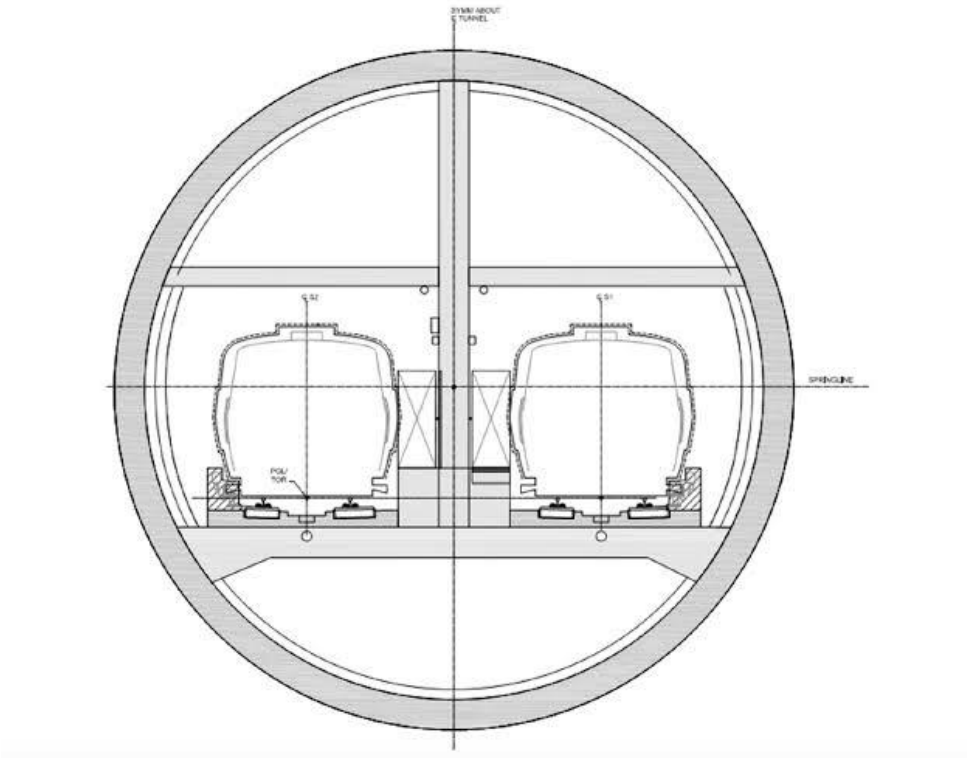


Figure 10-60: Arrangement of Single bore double track Tunnels

- **Twin bore single track tunnels (Germany, longer tunnels in Spain and UK):** **Figure 10-61** shows the arrangement of twin bore single track tunnels. A twin-bore tunnel configuration comprises two essentially parallel tubes, each housing one track. Considering the fire and life safety issues, cross passages shall be provided between the two tunnels to enable emergency egress from one tunnel to the other.

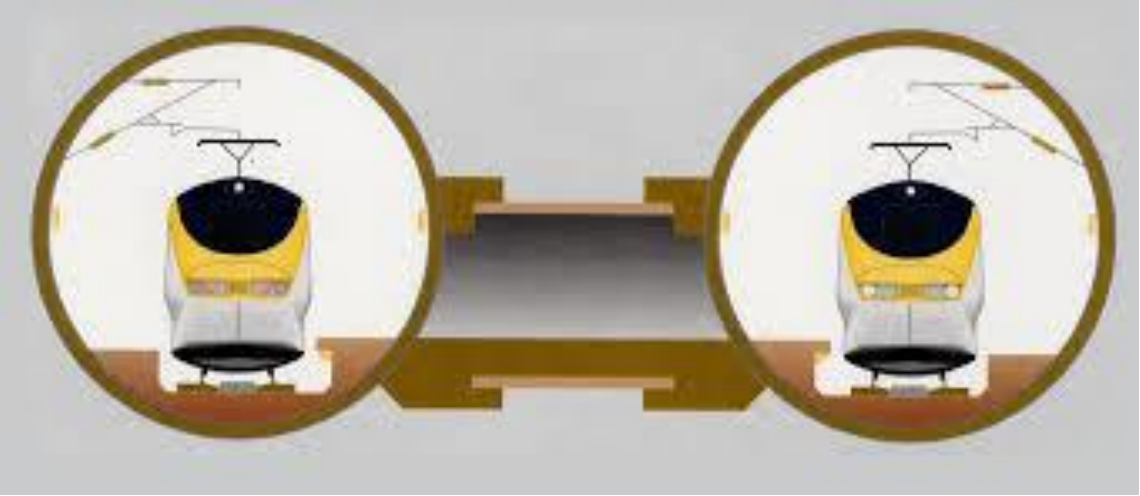


Figure 10-61: Arrangement of Twin bore single track Tunnels

10.14.2 Emergency Operation in HSR Tunnels

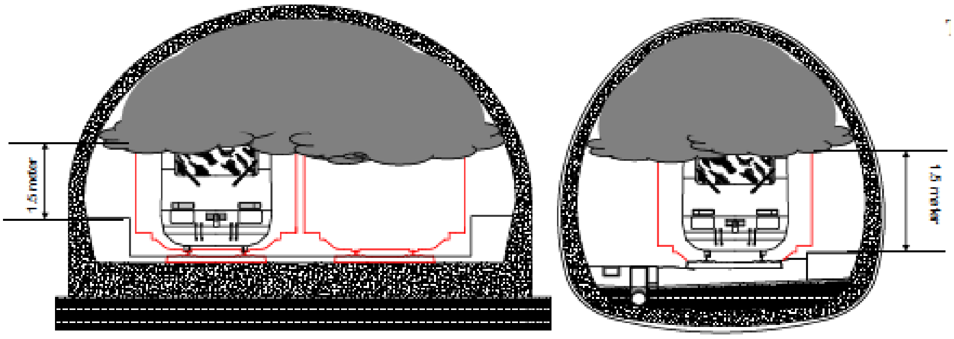


Figure 10-62: Emergency operation of Single and Twin tube tunnels

Figure 10-62 shows the twin and single tube tunnel during an emergency, in an emergency, it is most important to control the dispersion of smoke. While natural ventilation allows the removal of smoke only under certain boundary conditions, mechanical ventilation allows full control of smoke dispersion. Due to the smallest cross-section of a twin tunnel, a single-track system fills quicker with smoke than a single tube tunnel. Additionally, the limited size of the tunnel tube is a potential bottleneck for people escaping from the train and less space is available for rescue services in twin-tube tunnels. A twin-tube, single-track system, equipped with cross passages and a ventilation system, provides significantly shortened escape and rescue ways to smoke protected regions in the tunnel.

10.14.3 Purpose of Tunnel Ventilation System(TVS)

It is necessary to ensure that the toxic gases and other pollutants generated beyond acceptable limit do not take place and the thermal environment inside the tunnel at all the time is within tolerable limits for the passenger inside the tunnel. During the emergency of any fire or any train stalled condition inside the tunnel, the ventilation system provided inside the tunnel helps to evacuate the passengers safely.

10.14.4 Design of Ventilation Systems of Tunnels

The essential requirements of a ventilation system of the tunnel are as under: -

- It shall ensure enough airflow relative to moving the train, to keep the concentration of pollutant gases inside the tunnel within permissible limits
- It shall ensure enough airflow to prevent locomotives from overheating and to keep thermal effects within desirable limits
- It shall ensure that pressure transient is within acceptable limits

- It should provide a tenable environment along the path of egress from a fire incident in enclosed train ways
- It should produce airflow rates enough to prevent back layering of smoke in the path of egress within enclosed train ways
- It should accommodate the maximum number of trains that could be between ventilation shafts during an emergency.

The amount of airflow and type of ventilation arrangement required depends upon the level of concentration of pollutants and maximum temperature likely to be attained inside the tunnel due to the movement of the train. Level of concentration of pollutants and maximum temperature to be attained inside tunnel depends upon the following factors

- Type of locomotive
- Gradient inside tunnel
- Length of train
- Speed of train
- The time interval between two train
- Ambient temperature
- Length of tunnel
- Cross section of tunnel
- The direction of prevailing winds etc

TVS is provided in rail tunnel essentially to carry out the following functions:

a) Train pressure and draught relief during normal operation
b) Ventilation during maintenance periods, if required
c) Removal of smoke during emergency conditions
d) Providing fresh air supply to tunnel and maintenance of smoke free evacuation route during fire related emergencies.

There are various operating modes (scenarios) for the Tunnel Ventilation System. These are described as under:

10.14.4.1 Normal operation

The normal condition is when the trains are operating according to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements.

In the case of shorter tunnels, vent shafts may not be necessary and air exchange between tunnel and ambient can happen through portals.

Piston effect and therefore natural ventilation is enhanced in twin-tube single-track tunnels while it is lesser in single-tube twin track tunnels.

The desired tunnel air temperature is normally 40^0C for the proper functioning of wayside equipment and train air-conditioners. However, this temperature can be increased if wayside equipment can sustain a higher temperature for longer duration.

Generally, one-dimensional modelling and simulation are performed to assess the effectiveness of natural ventilation of the tunnel in maintaining acceptable level of temperature.

10.14.4.2 Congested operation

Congested conditions occur when delays disrupt the movement of trains. Delays may result in idling of a train in a tunnel section. Occasionally trains need to stop due to track blockage, power cut off or other reasons. Staying stationary for several minutes or even hours might lead to an unacceptable temperature rise and pollution level because of releases of waste heat (air-conditioning, cooling facilities, etc.). Without forced ventilation, excessive tunnel temperatures may result in reduced performance of coach air conditioners that may lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air-conditioner condenser coils. The ventilation strategy shall be such that fresh air will be supplied over stalled train to remove the excessive heat build-up near air-conditioners condensers and discharged via portal or vent shaft.

10.14.4.3 Emergency Conditions

When the train catches fire inside a tunnel, the major objective is to drive the train outside of the tunnel. Evacuation of passengers and firefighting is very much challenging inside a tunnel than outside.

If the fire incident occurs train is disabled in the tunnel, it is much important to control the dispersion of smoke to allow for the safe egress of passengers. The tunnel ventilation system may be required for most of the cases to control the movement of smoke and to provide a smoke-free path for the evacuation of passengers.

Generally, the design of the tunnel ventilation system worldwide follows NFPA 130 standard criteria. According to section 7.1.2 of NFPA 130-17,

- The mechanical ventilation system shall not be required if the tunnel length is less than or equal to 61m.
- The mechanical ventilation system shall be provided if the tunnel length is greater than 305m.

- For the tunnel length between 61m to 305m, an engineering analysis should be done to assess the feasibility of a non-mechanical ventilation system. If engineering analysis isn't performed, then a mechanical ventilation system shall be provided.

Major principles of ventilation in a rail tunnel are:

- **Longitudinal flow of air/smoke in incident tunnel:** The objective is to achieve the critical velocity across the annulus (at the location of a train inside the tunnel). The critical velocity is the minimum velocity required to avoid back layering of smoke (i.e. to push the smoke on one side of fire) which will protect the evacuating passengers upstream of the fire from the effects of the smoke shown in **Figure 10-63** and which provides defined access for rescue and firefighting services.

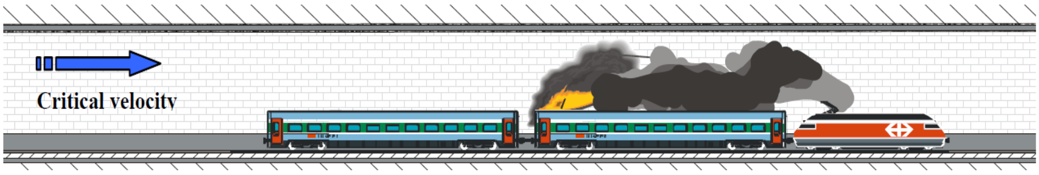


Figure 10-63: Arrangement of critical velocity applied in a tunnel section

The critical velocity through a tunnel during a fire is defined by the fire size, the tunnel area, height and gradient of the tunnel. The worst-case conditions are selected and applied uniformly across all the emergency responses for a tunnel with an appropriate safety factor. A velocity in the order of three meters per second would suffice but is subject to tunnel conditions.

- **Pressurization of the escape route:**

In the case of twin tube tunnels, the non-incident tube can be used for safe evacuation. Both tubes are connected by cross-passages. Whenever, a non-incident tube/tunnel is used for evacuation, fresh air is also supplied to pressurize the non-incident tunnel to prevent the smoke migration via open cross passages.

Longitudinal ventilation inherently implies the risk of moving smoke in the direction of escaping passengers and rescue services. Even if the position of fire is known exactly, e.g. in the middle of a train, this dilemma cannot be eliminated unless local smoke extraction is applied. However, properly operating the ventilation system can moderate the harmful effects of this ventilation principle. For example, moderate air velocity at the beginning of an incident will support the smoke stratification. The advantage of providing defined conditions outweighs by far the disadvantages of longitudinal ventilation.

Shorter tunnels may be ventilated with impulse-type ventilation systems. These include either jet fans or Saccardo nozzles. Jet fans or Saccardo nozzles are suited to the shorter tunnels as only a small pressure head is generated by moving airflows at the critical velocity. For longer tunnels, a significant amount of airflow will escape out of the local portal making the system more akin to a push and pull ventilation system.

Longer tunnels require more pressure head that can be delivered by an appropriate number of jet fans or Saccardo nozzle plant. In these tunnels, push and pull ventilation is required with a minimum of one ventilation building. This building is usually located at the center of the tunnel or biased towards the portal that requires a higher critical velocity. In this instance, slightly more than twice the quantity of air needed to achieve critical velocity is required to be handled by the building.

Outlined below are methods of ventilating rail tunnels:

- **Saccardo nozzles -** A Saccardo nozzle is a system that injects air at high velocity into the tunnel (usually at the portals) to generate longitudinal air movement. Saccardo nozzles have an advantage over jet fans in that they can generate large quantities of thrust (equivalent to several jet fans) with no encroachment on the tunnel area. The fan and equipment required to generate the airflows are hidden away in a plant room at the surface which can be isolated with dampers to protect fans and silencers from the effects of sonic pressure waves. Saccardo nozzles are placed at each end of the tunnel. **Figure 10-64** shows the arrangement of Saccardo Nozzles in tunnels.

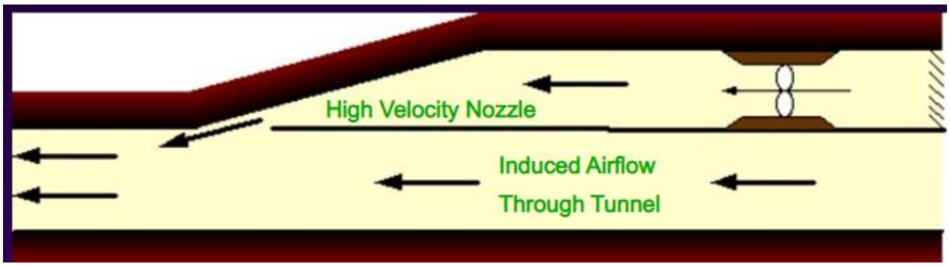
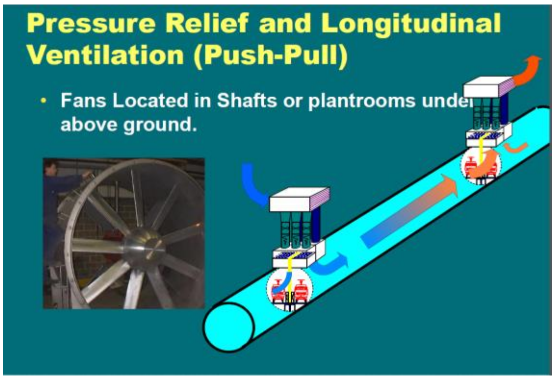


Figure 10-64: Arrangement of fresh air supply via Saccardo Nozzle

- **Jet fans -** May be installed within the rail tunnel; however, the jet fans will be subjected to sonic waves with high differential pressures generated by the trains moving at high speed. These differential pressures provide significant shock loads drastically reducing the life of the equipment and increasing the cost of maintenance.
- **Push and pull ventilation -** Ventilation stations may be installed on the surface along the route of urban rail tunnels for longer tunnels. Each building will be configured to supply or exhaust airflows to generate critical airflows across the train. Each ventilation building shall be required to supply or exhaust more than twice the required critical airflows to prevent smoke back layering in the tunnel, allowing for air movement in both directions along the tunnel. Typically, two to four bi-directional axial fans (with one standby) may be installed in a surface-mounted building with only the ventilation shaft required to be excavated to the

track way. Additionally, intermediate relief air shafts can be incorporated with little extra cost. Instead of directing airflows through the fans at the surface level, a damper can be opened to allow air to vent straight into the atmosphere. **Figure 10-65** shows the Push and pull type ventilation arrangement.



Pressure Relief and Longitudinal Ventilation (Push-Pull)

- Fans Located in Shafts or plantrooms unde above ground.

Figure 10-65: Arrangement of Push-Pull Longitudinal ventilation system

The adopted ventilation configuration would vary for each tunnel based on the tunnel type (single vs twin tube), tunnel length and depth, fire and life safety design and access restrictions.

10.14.4.4 Traction power requirement in Tunnels

Due to higher friction and pressure losses, the power demand for a single train travelling in a single tube, double-track tunnel with larger cross section is lower than in a twin tube, single-track tunnel. This effect is slightly compensated by the prevailing unidirectional flow of air in the twin tube, single track system, particularly with a high frequency of trains. **Figure 10-66** shows the traction power requirement in tunnels.

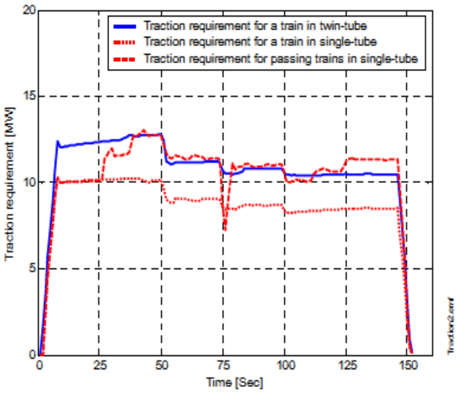


Figure 10-66: Traction power requirements in Tunnels

It is necessary to have 2 Nos of auxiliary substations for ventilation and lighting arrangement for the tunnel at Kozhikode station entry & exit area . The cost of tunnel ventilation and lighting have been included in the tunnelling cost.

10.14.4.5 Control

The control of ventilation systems shall be primarily from the Operation Control Centre (OCC) through the building management system. A set of ventilation scenario shall be developed so that the operator need only select the appropriate ventilation scenario and the fans will automatically be correctly configured. **Figure 10-67** shows the control and monitoring of tunnel ventilation equipment from OCC

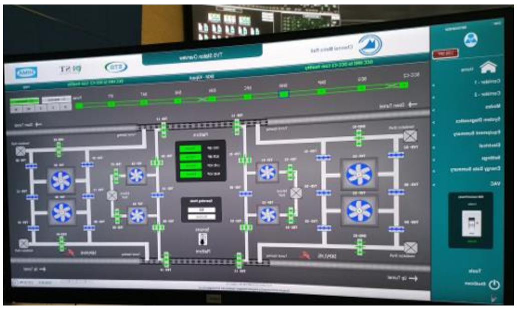


Figure 10-67: Tunnel ventilation monitoring and Control view from OCC

As per Indian railway bridge manual, on single line sections, tunnels having length up to 2 kms, may not require provision of artificial ventilation but it should be ensured that levels of concentration of pollutants during passage of trains are not likely to exceed threshold levels. Tunnels having length more than 2 kms may require provisions of artificial ventilation, by means of shaft with or without provision of fans, depending upon results of simulation studies.

10.14.4.6 Codes and Standards

The concept of Tunnel ventilation is guided by the following standards;

- NFPA 130, ASHRAE handbook and SEDH – Subway environment design handbook.

10.15 RENEWABLE ENERGY

K-Rail proposes to use solar and other renewable energy for this project as green energy and sustainable project.

10.15.1 Solar Energy

Solar energy is the best form of sustainable energy. It is recommended to have the following provisions for the generation/purchase of solar energy

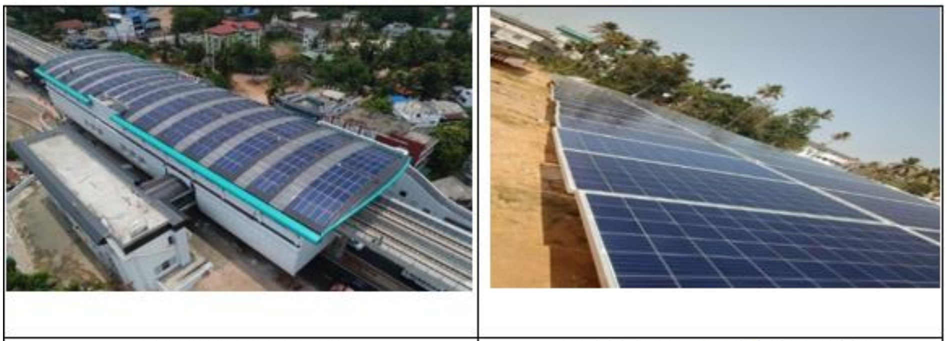
- Provision of fixing Solar panels on the rooftop of the buildings (rooftop of all station building, depot building, Traction substation, Viaduct etc)

- Provision of Ground mounted solar system, where free land is available for a longer period
- Provision of Solar plants in intrastate/ interstate

Clearance/ No objection certificate (NOC) needs to be obtained before commencement of the work / evacuation of solar energy

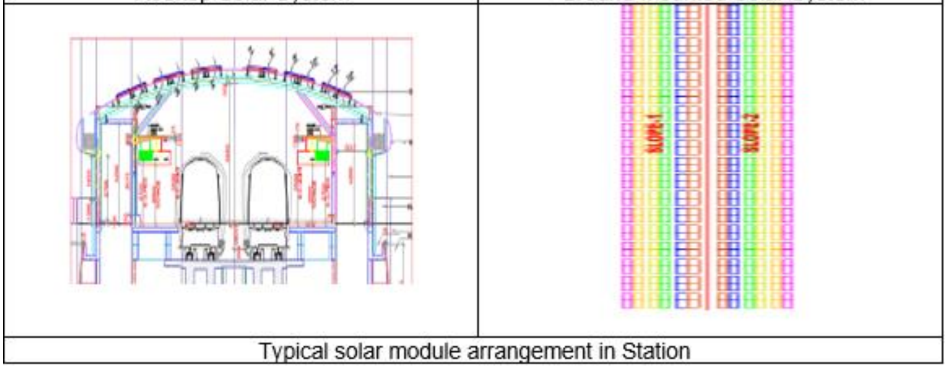
1. Preliminary approval shall be obtained from KSEBL and Electrical inspectorate before commencing the installation work
2. After completion of the installation work, Sanction to be obtained from Electrical inspectorate
3. The signing of connection Agreement with KSEBL
4. The signing of Banking agreement with KSEBL

Figure 10-68 shows the mounting arrangements of solar panels in roof top and Ground level



Rooftop Solar System

Ground-mounted Solar System



Typical solar module arrangement in Station

Figure 10-68: Mounting arrangements of solar panels

Table 10-30 shows the tentative plant capacity of Stations, Depot, viaduct and free land available in Depot.

Table 10-30 : Tentative plant capacity of Stations, Depot and Viaduct

Sr No	Location	Tentative Plant Capacity (MWp)
1	Station building and other service building	15
2	Depot building and other depot areas	5
3	Viaduct, compound wall fencing and trackside	80
	Total	**100 MWp**

10.15.1.1 Applicable standards

The PV modules used shall be as per IEC 62804 and the modules used must qualify to the latest edition of IEC PV module qualification test or equivalent BIS standard crystalline silicon solar cell modules IEC 61215/IS 14286. Also, the modules must conform to IEC 61730 part-1&2 (requirement of construction, testing for safety qualification). For the PV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify IEC 61701/ IS 61701

All switches and circuit breakers, connectors shall conform to IEC 60947 Part (1,2&3)/IS 60947 Part (1,2&3)

The power conditioning units/inverters shall comply with applicable IEC/equivalent BIS standard for efficiency measurements and environmental tests as per standard codes IEC 61683/IS61683 and IEC 60068-2 /equivalent BIS standard.

10.15.1.2 Recommendation

It is recommended to provide the grid tied Photo Voltaic (SPV) plants on roof top of Station and Depot buildings. Also, it is recommended to provide Solar panels on compound wall of Track area, Viaducts ,intrastate/interstate etc. and ground mounted solar panels on free lands . The Grid connected SPV system shall be without battery and designed with necessary features to supplement the grid power during day time.

The grid connected solar system shall have the following facilities

10.15.1.3 Integration of SPV power with Grid

The output power from SPV would be fed to the inverters which converts DC produced by SPV array to AC and feeds it into the main electricity grid after synchronization. In the case of grid failure, the solar PV system shall be out of synchronization and shall be disconnected from the grid. Once DG set comes into the service PV system shall again be synchronized with DG supply and feeds the solar energy.

10.15.1.4 Data Acquisition system

Data acquisition system shall be provided for each of the Solar plant

Data logging provision for plant control and monitoring, time and date stamped data logs for analysis

Solar Irradiance: An integrated pyranometer shall be provided with the sensor mounted in the plane of the array readout integrated with data logging system

Temperature: Temperature probes for recording the solar panel temperature and the ambient temperature shall be provided complete with readouts integrated with data logging system

The following parameters shall be accessible via the operating interface display in real-time separately for solar plant

- AC Voltage
- AC output current
- Output Power
- Power produced
- Power factor
- DC input voltage
- DC input current
- Time Active
- Time disabled

10.15.1.5 Metering

The bidirectional electronic energy meter shall be installed for the measurement of import /export of energy. All meters installed shall be comply with the CEA (installations and operation of meters) regulation 2006 and subsequent amendments.

10.15.2 Wind Energy

Wind energy describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. The provision to purchase wind energy to be explored. **Figure 10-69** shows the arrangement of windmills.

Figure 10-69: Windmills

Clearance/ No objection certificate (NOC) needs to be obtained before commencement of the work / evacuation of wind energy

1. Preliminary approval shall be obtained from the Agency for Non - conventional Energy and Rural Technology (ANERT)
2. After completion of the installation work, Sanction to be obtained from National Institute of Wind Energy (NIWE)
3. The signing of connection Agreement with KSEBL
4. The signing of Banking agreement with KSEBL

10.15.3 Models adopted for Renewable Energy

There are different types of execution models available in India:

1. **RESCO Model:** A Renewable Energy Service Company (RESCO) is an energy service company, which provides energy to consumers from renewable energy sources, usually solar photovoltaics, wind power or micro -hydro.

   The main characteristics of a RESCO are:

   - The household serviced does not own the generation equipment, which is owned by an external organization (RESCO)
   - The user does not carry out maintenance, all maintenance and repair service will be done by RESCO;
   - The user shall pay the energy charge per unit consumption

2. **CAPEX Model:** In this type of model, all the capital and operational expenses shall be borne by the user.

10.15.4 General Conditions and Charges for use of Renewable Energy (K-Rail Premises)

For the use of the transmission and distribution system by K-Rail having renewable energy system with capacity more than 1MW at the same premises for his own use, K-Rail shall pay the following charges to KSEBL

1. 5% of the energy injected into the grid of the transmission and /or the distribution licensee shall be accounted towards grid support charges and the balance shall be treated as net energy
2. If the net energy during a time period (normal hours, peak hours and off- peak hours) in a billing period is fully consumed by the K-Rail during the same period (normal hours, peak hours and off peak hours) for such quantum of renewable energy , K -Rail is exempted from the transmission charges , wheeling charges and losses in transmission system and distribution system approved by commission
3. The K-Rail is permitted to account the renewable energy injected in a time period (normal, peak and off-peak hours) during the billing period against the consumption in a different time period during the same billing period, subject to the following conditions
    a. 80% of the net energy injected in time periods other than peak hours be allowed to be adjusted against peak hour consumption
    b. The net energy injected during peak hours shall be allowed to be adjusted 100% during peak hours and the balance shall be allowed to be adjusted 120% during other time blocks
    c. At all other time periods, except energy injection during peak hours ,100% of the net energy in any time period will be allowed to be adjusted against the consumption during the time period other than peak hours.
4. The excess energy if any available at the end of the billing period is allowed to be banked and carried forward to the subsequent billing period of the settlement period subject to the following
    a. 95% of the energy so banked only will be allowed to be adjusted in the subsequent billing period of the settlement period and 5% of the banked energy shall be accounted towards banking charges of the distribution licensee
5. The KSEBL shall pay within one month for the net surplus energy available at the credit of the K-Rail at end of the settlement period at the average power purchase cost of the licensee approved by the KSERC
6. The K-Rail , who installed renewable energy system at the same premises is exempted from the payment of transmission charges, wheeling charges , transmission losses and distribution losses for the quantum of energy

generated from the RE plant and adjusted against his consumption during the settlement period in the same premises.

10.15.5 General Conditions and Charges for use of Renewable Energy (Intrastate)

1. If K-Rail is using the transmission and /or distribution system of the KSEBL for wheeling the energy generated from the renewable energy system to a different location within state, shall pay the following charges approved by KSERC from time to time
    a. Transmission charges
    b. Wheeling charges
    c. Transmission losses and distribution losses
    d. Any other charges approved by KSERC
2. Captive consumers who maintain the contract demand with the KSEBL are required to pay transmission charges only on per unit basis at the rates approved by KSERC
3. 5% of the energy injected into the grid of the transmission and /or the distribution licensee shall be accounted towards grid support charges and the balance shall be treated as net energy
4. If the net energy , after deducting the approved transmission and /or distribution loss, injected from the renewable energy system during a time period (normal hours, peak hours and off-peak hours) in a billing period is fully consumed by the K-Rail during the same period (normal hours, peak hours and off peak hours) for such quantum of renewable energy , K-Rail is exempted from the transmission charges , wheeling charges and losses in transmission system and distribution system approved by commission
5. The K-Rail is permitted to account the renewable energy injected in a time period (normal, peak and off-peak hours) during the billing period against the consumption in a different time period during the same billing period, subject to the following conditions
    a. 80% of the net energy injected in time periods other than peak hours be allowed to be adjusted against peak hour consumption
    b. The net energy injected during peak hours shall be allowed to be adjusted 100% during peak hours and the balance shall be allowed to be adjusted 120% during other time blocks
    c. At all other time periods, except energy injection during peak hours ,100% of the net energy in any time period will be allowed to be adjusted against the consumption during the time period other than peak hours.

6. The excess energy if any available at the end of the billing period is allowed to be banked and carried forward to the subsequent billing period of the settlement period subject to the following
    a. 95% of the energy so banked only will be allowed to be adjusted in the subsequent billing period of the settlement period and 5% of the banked energy shall be accounted towards banking charges of the distribution licensee
7. The KSEBL shall pay within one month for the net surplus energy available at the credit of the K-Rail at end of the settlement period at the average power purchase cost of the licensee approved by the KSERC

10.15.6 General Conditions and Charges for the purchase of Open Access Power

If K-Rail is purchasing power from an independent renewable power generator by availing open access using distribution system of KSEBL. In such cases K-Rail shall pay the following charges to KSEBL as approved by KSERC from time to time

a. Transmission charges
b. Wheeling charges
c. Cross subsidy surcharges
d. Transmission losses and distribution losses
e. Any other charges approved by KSERC

10.16 ENERGY-SAVING MEASURES

Energy charges of any SilverLine Rail system constitute a substantial portion of its operation and maintenance (O&M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The traction power consumption increases with an increase in train frequency /composition in order to cater more traffic. The proposed system of SilverLine rail includes the following energy-saving features.

1. Modern rolling stock with 3 phase VVVF drive and lightweight Aluminium coaches are proposed, which has the benefits of low specific energy consumption and almost unity power factor
2. Rolling stock has regeneration features and it is expected that 15% of total traction energy will be regenerated and feedback to 2x25kV OCS to be consumed by nearby trains
3. Use of LED lights in Stations, Depot and Tunnel and effective utilization of natural light is proposed in the station buildings
4. Use of solar lights for external and parking lighting
5. Use of intelligent controllers/timers/sensors (scheduling control, occupancy sensor, daylight sensor and lumen maintenance) for automatic operation of

lights.Lighting controls allow lighting to be turned on or completely off when it is not needed

6. Use of energy efficient air-conditioned system and Thermal energy storage system will be adopted for major centralized AC system like depot, OCC and administrative buildings.
7. Machine room less type lifts with gearless drive will be provided with 3 phase VVVF drive
8. The proposed heavy-duty public service escalator will be provided with 3 phase VVVF drive, which is energy efficient and improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by the passenger
9. The latest state of energy efficient electrical equipment (Transformer, motors, pumps, HVAC, light fittings etc) to be incorporated into the system design
10. To achieve the energy efficiency during operation , it is proposed to have energy monitoring and metering system (local and remote monitoring system) in station and Depot
11. Implementation of annual energy audits for SilverLine buildings - It is proposed to carryout energy audit to explore the fields where further savings can be done
12. Powerfactor shall be kept as unity . A high power factor is generally desirable in a system to reduce the loss and improve the voltage regulation at the load end .It is proposed to use power factor correction panel in Traction substation and auxiliary susbstation .
13. Periodic loss monitoring study may be conducted for all the transformers
14. Stations are to be designed to attain Green building certification of IGBC
15. Energy saving and conservation concepts shall be circulated among the staff,users and passengers from the beginning and periodically.

10.17 SUSTAINABLE TRANSPORTATION

This project is committed to develop an environmentally and economically sustainable, long term alternative to the current transportation systems in Kerala, which will increase transportation efficiency, use 100 percent of renewable energy and incorporate additional sustainability practices.

Although rail is one of the world’s oldest transportation methods, it continues to be one of the most energy efficient ways to move large number of people. Experience both in India and abroad illustrate that rail travel provides an efficient alternative for the traveller, who wants to reach the key, central destinations and important cities without the delay and hassle of air travel, and in a faster, less polluting, safer and more efficient method than driving.

In 2025, it is estimated that 79934 passengers will use the SilverLine corridor between Thiruvananthapuram and Kasaragod, which requires approximately 279 million units of energy. In 2052, approximately 497 million units of energy will be required to transport 158946 passengers among the stations between Thiruvananthapuram and Kasaragod. The energy required to move similar numbers of passengers by car would be thrice the energy required for SilverLine.

For SilverLine operation, 2x25kV ,50Hz Autotransformer type feeding system is adopted for main line and each of the traction substation is located at approximately 70 - 100 km spaced along the alignment. The system will also capture the energy from the braking and deceleration of the train. This energy estimated to be nearly 15 percent of the total power of the system. This can be used by other trains.

Energy-efficiency and maximizing recovery of electricity are just part of the plans. In 2025, it is proposed to adopt a policy goal to run operations with 100 percent of renewable energy. Through proper planning and co-ordination with utility companies and regulatory agencies, it is proposed to achieve this goal to procure or producing enough renewable energy to feed into the grid to offset the amount the train uses.

This net-zero approach means that renewable energy developers can find the most economical locations to develop and distribute energy to the grid .Simultaneously ,through a formal call to industry process, it is proposed to ascertain the capacity, and the strong interest companies ,to provide renewable energy to the system. Besides, it is being explored to produce solar or other renewable energy on SilverLine rail canopies, roof, viaduct, free land and other maintenance facilities as well as other structures.

In this manner, the SilverLine rail system will be ahead of the clean transportation curve and leading by example.

10.17.1 Rail as Green as we can make it

K-Rail is proposing to develop a sustainability policy in collaboration with the Indian Institute of Management (IIM) - Ahmedabad and other nodal agencies. A preliminary meeting was held with IIM - Ahmedabad and more initiative to be launched to make the basic framework and policies to be adopted.

Strategies proposed to be adopted during construction include items such as requirements for recycling all steel and concrete; diversion of construction waste from landfills through reuse and recycling; use of new, low emission construction equipment and replacement of inefficient truck engines and irrigation pumps. K-Rail will also be working with agencies to implement an urban forestry program to offset greenhouse gas (GHG) emissions associated with construction. This program will deliver additional benefits such as providing shade and recreation for communities within the train corridor.

The Station buildings, depot, administrative building and other service buildings may be designed based on the platinum rating standard of Indian Green Building Council (IGBC)

So, what's the bottom line for high-speed rail as it relates to energy future?

Starting in 2025, during the system's first year of operation, K-Rail anticipates a ramp-up in usage as travellers begin to switch from driving or flying to take SilverLine rail. Every subsequent year, as the system is projected to increase riders, it is expected to continue reductions in greenhouse gas (GHG) emissions and air pollutants.

In 2025, the SilverLine rail system will reduce approximately 287994 tonnes of carbon dioxide equivalent. By 2052, the system will reduce approximately 594636 tonnes of carbon dioxide equivalent.

Hence, the proposed Silver Line rail is a game changing form of sustainable transportation, first of its kind in India and may also be a few in the world

Table 10-31 : Details of Power line crossing from Thiruvananthapuram to Kasaragod

Chainage	Tower/Cable	Voltage Level
286188	OH	11kV + LT
285933	OH	LT
285133	OH	11kV + LT
284733	OH	11kV + 33kV
284733 - 284633	TOWER	110kV
283733 - 283833	OH	11kV +33kV + LT
283233 - 283133	TOWER	110kV + 33kV
282633 - 281433	TOWER	110kV
282433	OH	11kV
280683 - 280733	TOWER	110kV
280833	OH	11kV
280833	OH	11kV
280433	TOWER	110 kV
280433	TOWER	110 kV
279533	OH	LT
278933	OH	LT
277333	OH	11kV + LT
278333	OH	11kV
277733	OH	11kV + LT

Chainage	Tower/Cable	Voltage Level
277633	OH	11kV + LT
276933	OH	11kV + LT
276533	OH	11kV + LT
275833	OH	11kV + LT
275633	OH	LT
274933	OH	11kV + LT
274433	OH	11kV + LT
273233	OH	11kV + 11 kV + LT
273033	OH	11kV + LT
272633	OH	LT
272633	OH	LT
272233	OH	LT
271833	OH	11kV + LT
721133	OH	11kV + LT
270933	OH	11kV + LT
269033	OH	LT
268633	OH	11kV + LT
268483	OH	11kV + LT
267633	OH	33kV
267833 - 267733	OH	33kV
267133	OH	11kV + LT
266583	OH	11kV + LT
266433	OH	11kV + LT
265833	OH	11kV
265333 - 265383	TOWER	110kV
263883	OH	11kV
263833	OH	11kV + LT
263633	OH	11kV + LT
262883	OH	LT
318214 - 318614	OH	11kV + LT
317414	OH	LT
313433	TOWER	110kV
309733	OH	33kV
309433	OH	11kV + LT

Chainage	Tower/Cable	Voltage Level
306533	OH	11kV + LT
306433	OH	11kV + LT
305933	OH	11kV + LT
305433	OH	11kV + LT
304633	OH	11kV + LT
304333	OH	11kV + LT
302533	OH	11kV + LT
301533	OH	110kV
301333	OH	LT
299733	OH	11kV + LT
298633	OH	11kV + LT
297033	OH	11kV + LT
297133	OH	11kV
296483	OH	LT
295133	OH	11kV + LT
294833	OH	11kV + LT
293833	OH	11kV + LT
292233	OH	11kV + LT
292033	OH	11kV + LT
290833	OH	11kV + LT
290433	OH	11kV + LT
290833	OH	11kV + LT
290433	OH	11kV
290033	OH	LT
289633	OH	11kV + LT
289033	OH	11kV + LT
288533	OH	11kV + LT
288033	OH	LT
287933	OH	LT
287233	OH	11kV + LT
287133	OH	11kV + LT
286633	OH	11kV + LT
286183	OH	11kV + LT
319514 - 319414	SUBSTATION	110 kV Tirur Traction substation

Chainage	Tower/Cable	Voltage Level
319714	TOWER	110kV
319714	UG CABLE	11kV
319514 - 319414	UG CABLE	11kV
321514	OH	11kV + LT
321514 - 323014	OH	11kV + LT
324614 - 324514	OH	LT
326464	OH	11kV
326814	OH	11kV
327114	OH	LT
332414	OH + UGC	11kV + LT
333214	UGC	11kV
334714	OH	11kV + LT
335414	OH	LT
339514	OH	11kV + LT
339414	OH	11kV + LT
342314	OH	11kV
342314	UGC	11kV
333214	UGC	11kV
335714	OH	11kV + LT
335414	OH	LT
339514	OH	11kV + LT
339414	OH	11kV + LT
342314	OH	11kV
342314	UGC	11kV
343614	OH	11kV + LT
346814	OH	LT
347314	OH	11kV + 11 kV ABC + LT
350014 - 350214	OH	11kV
351014	OH	11kV + LT
350514 - 350814	OH	11kV
354314	OH	LT
358264	OH	11kV + LT
358414	OH	11kV ABC + LT

Chainage	Tower/Cable	Voltage Level
358764	OH	LT
358864	OH	LT
358864 - 359014	OH	LT ABC
359714	OH	11kV + LT ABC
359914	OH	LC
360114	OH	11kV + LT
360614	OH	11kV + LT
360914	OH	11kV + LT
361014	OH	11kV
316121	OH	LT
361614	OH	LT
309714 - 361914	OH	11kV + LT
363014	OH	LT
363014 - 363814	OH	LT
364114	OH	LT
363514	OH	LT
363814	OH	LT
364014	OH	LT
344814	OH	LT
364814 - 365814	OH	LT
368214	OH/UGC	RMU + 11kV + LT + UGC 11kV
373814	OH	UGC 11kV + 11kV DP structure
375814	UGC	11kV UGC
379014	OH	LT
380814	OH	LT
382914	OH/UGC	11kV + LT + 11kV UGC
385414	OH	LT
385714	OH	LT
391114	OH	LT
391814	OH	11kV + LT
393514	OH	11kV + LT
393818	OH	LT
394314	OH	11kV + LT
400314	OH	LT

Chainage	Tower/Cable	Voltage Level
400514	OH	LT
401114	OH	11kV ABC+ LT
401314	OH	LT
402014	OH	11kV + LT
402464	OH/UGC	11kV + LT + Transformer 100kVA
402614	OH	11kV + LT + DP Structure
402564	OH	11kV + LT
403764	OH	11kV + LT
404164	OH	11kV + LT
404814 - 408764	TOWER	110 kV
408764 - 409414	TOWER	110 kV
405814	OH	33kV + 11kV + LT
407864	OH	11kV + LT
407914	OH	LT
408764	TOWER	110 kV
408764	OH	11kV + LT
409514	OH	11kV + LT
411114	OH	LT
414114	OH	LT
415714	OH	LT
416364	OH	LT
416364	OH	LT
417014	OH/UGC	11kV + UGC 11kV + LT
420414	OH/UGC	11kV + UGC 11kV + LT
419014 - 419114	OH	11kV + LT
420714	OH	11kV + LT
421414	OH	11kV + LT
421514	OH	LT
422314 - 422414	OH	LT
422414	OH	11kV + LT + DP Structure
423514	OH	LT
425214	OH	LT
425514	OH	LT

Chainage	Tower/Cable	Voltage Level
427614	OH/TOWER	110 kV
426814	OH	11kV + LT
427414	OH	11kV + LT
427614	OH	LT
428314	OH	11kV + LT
428414	OH	11kV + LT
428914	OH	11kV + LT
429464	OH	11kV + LT
430214	OH	11kV + LT
431176	OH	11kV + LT
432476	OH	11kV + LT
433976	OH/Tower	110kV + 11kV + LT
435576	OH	11kV + LT
437226	OH	11kV + LT
437876	OH	11kV + LT
439276	OH	11kV + LT
440726	OH	11kV + LT
440976	OH	11kV + LT
441976	UG	110kV cable
443776	OH	11kV + LT
444326	OH	11kV + LT
444676	OH	11kV + LT
447226	OH	LT
447476	OH	LT
450376	OH	11kV + LT
455176	Tower	110kV
455676	OH	11kV + LT
457776	OH	11kV
459376	OH	LT
470526	OH	11kV + LT
470776	OH	11kV + LT
470876	OH	11kV + LT
472726	OH	LT
474376	OH	11kV
476126	OH	LT

Chainage	Tower/Cable	Voltage Level
484776	UG	33kV + 11kV x 2Nos
489076	OH	11kV + LT
495226	UG	11kV
503826	OH	11kV + LT x 2Nos
508826	OH	11kV
509276	OH	Railway SSP infringing
520676	UG	11kV
521626	OH	11kV
522076	OH	11kV + LT
522376	OH	LT
522976	OH	11kV + LT
523826	OH	11kV + LT
524276	OH	11kV + LT
524776	OH	11kV + LT+ Rail crossing
528326	OH	11kV
531676	OH	Railway SSP infringing
531976	OH	11kV + LT

Table 10-32 : Applicable standard

Standard	Standard Code
Railway applications – fixed installations – electric traction overhead contact line	EN - 50119
Railway application – Power supply and rolling stock technical criteria for the coordination between power supply and rolling stock to achieve interoperability	EN - 50388
Railway applications – fixed installations – Electrical safety, earthing and the return circuit	EN - 50122
Railway applications – Insulation coordination	EN - 50124
Railway applications – fixed installations – Supply voltage of traction systems	EN -50163, IEC - 60850

Standard	Standard Code
Railway applications – The specification and demonstration of reliability, availability , Maintainability and safety	EN - 50126
Insulators for overhead lines with nominal voltage above 1 kV - insulator units of ceramic material or glass for ac systems - Characteristics of insulator units lid type and rod type	EN 60305
Locking devices for assemblies of ball-and-socket suspension insulator units - Dimensions and tests	EN 60372
Specifications of the technical quality of Sulfur hexafluoride (SF6) for use in electrical devices	EN 60376
Railway applications - Fixed installations - Electrical safety, provisions for the return currents and earthing - Part 3: interactions between traction systems for alternating current and direct current	EN 50122-3
EMC - Generic standards - Emission - 2 - Industrial Environment;	EN 50081-2
EMC - Generic standards - Immunity - 2 - Industrial Environment;	EN 50082-2
Supply voltage of traction systems;	EN 50163
Railway applications - EMC 1 - Generalities	EN 50121-1
Railway applications - EMC 2 - Disturbances to local residents;	EN 50121-2
Railway applications - EMC 4 - Signalling and Telecommunications;	EN 50121-4
Railway applications - EMC 5 - Fixed installations	EN 50121-5
Railway applications - Fixed installations - Particular requirements for AC equipments - Part 3-1: Measurement, control and protection for specific use in systems AC traction - application guide	EN 50152-3-1

Standard	Standard Code
Railway applications - Rolling stock - Pantographs: Characteristics and tests - Part 1: Pantographs for HSL vehicles	EN 50206-1
Railway applications - Power collection system pick-up- Requirements and validation of measurements of the dynamic interaction between pantograph and catenary	EN 50317
Railway applications - Fixed installations - Traction transformers	EN 50329
Railway applications - Power collection system pick-up- Methods of test of pantograph contact strips carbon	EN 50405
Railway Application Electromagnetic Compatibility Part 5: Fixed Power Supply Installations	EN 50121-5
Hot Rolled Products of Non-Alloy Structural Steels: Delivery condition	EN 10025
Structural Steel I and H Sections – Tolerances on Shape and Dimensions	EN 10034
Hot Rolled Steel Equal Flange Tees with Radiused Root and Toes – Dimensions and Tolerances on Shape and Dimensions	EN 10055
Structural Steel Equal and Unequal Leg Angles	EN 10056
Quenched and Tempered Steels	EN 10083
Stainless Steels	EN 10088
Aluminium and Aluminium Alloy	EN 1301
Voltage characteristics of electricity supplied by public distribution networks	NF 50160
Standards for transformers PART 1: Current transformer	EN 60044-1

Standard	Standard Code
Standards for transformers PART 2: Inductive voltage transformers	EN 60044-2
Standards for transformers PART 3: Combined transformers	EN 60044-3
Standards for transformers PART 6: Prescriptions on current transformers protection in transient functioning	EN 60044-6
Technical standards for testing high voltage	EN 60060
Standards for insulation coordination : Part 1	EN 60071-1
Standards for insulation coordination : Part 2	EN 60071-2
Standards for insulation coordination : Part 3	EN 60071-3
Standards for power Transformers	EN 60076
Standards for power transformers part 3: Insulation levels, dielectric tests and external insulation clearances in air.	EN 60076-3
Standards for power transformers part 4: A Guide for lightning impulse tests and operating shock - Power transformers and reactors	EN 60076-4
Standards for power transformers part 6: Reactors	EN 60076-6
Standards for power transformers part 10: Determination of noise levels	EN 60076-10
Standards for power transformers Part 11: Dry Type	EN 60076-11
Standards for power transformers part 12: Loading guide for transfomer Power Dry type	EN 60076-12
Standards for power transformers from 13: self-protected transformer immersed in a dielectric liquid	EN 60076-13
Railway applications - Track - Construction machinery and maintenance exclusively via railways - Part 1: technical requirements for traffic	EN 14033-1

Standard	Standard Code
Railway applications - Track - Construction and maintenance machinery exclusively via railways - Part 2: technical requirements for job	EN 14033-2
Railway applications - Track - Construction and maintenance machinery exclusively via railways - Part 3: technical requirements for safety	EN 14033-3
Railway applications - power and control cables with fire behaviour specify for railway rolling stock - Part 1: General requirements	EN 50264-1
Railway applications - power and control cables with fire behaviour specify for railway rolling stock - Part 2: Single-conductor cable	EN 50264-2
Electric Traction Over Head contact lines	EN 50119
Railway Application - Protective provisions relating to electrical safety and earthing;	EN 50122-1
Railway applications - Fixed installations - Part 2: measures to protect against the effects of stray currents from electric traction DC	EN 50122-2
Railway applications - Insulation coordination - Part 1: Basic requirements - external clearances in air and creepage distances for all electrical and electronic equipment	EN 50124-1
Railway applications - Insulation coordination - Part 2: Overvoltage and related protection	EN 50124-2
Railway applications - Fixed installations - Electric power train - Special requirements for composite material insulators	EN 50151
Railway applications - Fixed installations - Particular requirements for ac devices - Part 3-2: Measurement, control and protection for specific use in power train systems AC - single-phase current transformers	EN 50152-3-2

Standard	Standard Code
Railway applications - Fixed installations - Particular requirements for ac devices - Part 3-2: Measurement, control and protection for specific use in power train systems AC - single-phase voltage transformers	EN 50152-3-3
Railway applications - Fixed installations - Harmonisation of the rated values and tests on converter groups	EN 50327
Railway applications - Fixed installations - Electronic power converters for substations	EN 50328
Railway applications - Fixed installations - Electric traction - Assemblies for installation synthetic cables for support of overhead contact lines	EN 50345
Environmental conditions for equipment - Part 2 - fixed electrical installations;	EN 50125-2
Specification and demonstration of dependability - RAMS;	EN 50126
Railway applications - Fixed installations - Electric traction - Copper wire groove and copper alloy;	EN 50149
Particular specifications ac devices - Part 1: Circuit-breakers with a single phase above 1 kV;	EN 50152-1
Particular specifications ac devices - Part 2: Single-phase disconnectors, earthing switches and switches disconnectors above 1 kV;	EN 50152-2
Particular specifications ac devices - Part 3: Measurement, control and protection for specific use in systems AC power traction, single-phase current transformer	EN 50152-3-2
Particular specifications ac devices - Part 3: Measurement, control and protection for specific use in systems AC drive, single-phase voltage transformer	EN 50152-3-3
Conductors for overhead lines. conductors stranded circular wired in concentric layers;	EN 50182

Standard	Standard Code
Fixed installations - Fixed transformers;	EN 50329
Guidelines for the control and treatment of Sulfur hexafluoride (SF6) taken from electrical equipment and specification for reuse (01 March 2005);	EN 60480
electromagnetic compatibilities	EN 300827
EMC - Part 4: technical Testing and measurement - Section 12: immunity tests with oscillatory - Basic publication in EMC;	EN 61000-4
Uninterruptible power supply (UPS) - Part 2: Requirements for electromagnetic compatibility (EMC)	EN 50091-2
Railway applications - Fixed installations - Electronic power converters for substations	EN 50328
Metal oxide surge arresters without gaps;	EN 60099-4
Common methods of testing of insulation for electrical cables;	EN 60811
standard voltage	IEC 60038
Instructions related to protection current transformer for transient state response	IEC 44-6
Expulsion type lighting arresters	IEC 99-2
Non-linear resistor type gapped surge arresters for A.C. system /Metal oxide surge arrester without gaps for a.c. systems	IEC 60099-1 & 4
standard frequencies	IEC 196
New insulating mineral oil specification for transformers	IEC 296
Dimensions of mechanical structures of the 482.6 mm (19 in) series	IEC 297-3
A.C. metal enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 72,5 kV	IEC 298

Standard	Standard Code
Insulators and fittings for overhead lines. Insulators of ceramic material or glass for overhead line with nominal voltage higher than 1000 V. Requirements	IEC 383-1 & 2
Extruded solid dielectric insulated power cables and their accessories for rated voltage from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)	IEC 502-2
Determination of transformer and reactor sound level	IEC 551
Electronic equipment specification	IEC 571
Graphical symbols for diagrams. Part 2: symbol elements, qualifying symbols and other symbols having general application.	IEC 617-2
Alkaline secondary cells and batteries- Sealed nickel-cadmium parallelepiped rechargeable single cells	IEC 622
Common specifications for high-voltage switchgear and control gear standards	IEC 694
Classification of environmental conditions- Classification of groups of environmental parameters and their severity- Stationary use at weather protected locations.	IEC 721-3-3
Classification of environmental conditions- Classification of groups of environmental parameters and their severities- Stationary use at non weather protected locations.	IEC 721-3-4
Dry type power transformer	IEC 726
Electromagnetic compatibility for industrial-process measurement and control equipment – General introduction– Electrostatic discharge requirements– Radiated electromagnetic field requirements- Electrical for transient/burst requirements Shock wave requirements Immunities to disturbances conducted and induced by radio fields	IEC 801- 1, 2, 3, 4, 5, 6 EN - 50121

Standard	Standard Code
Power cables with extruded insulation and their accessories for rated voltage above 30kV (Um = 36 kV) up to 100 kV. Test methods and requirements.	IEC 840
Earth mesh and earth procedure code	IEC 865, IEEE - 80, IS 3043
Hard-drawn aluminium wire for overhead line conductor	IEC 889
Programmable controllers	IEC 1131
Measuring transformers	IEC 60044 - 1, 2
High Voltage test;	IEC 60060
High-voltage test Part 1, Definitions and general requirements	IEC 60060-1
High-voltage test Part 2; Measurement System	IEC 60060-2
High Voltage test, definitions and Requirements for on-site testing	IEC 60060-3
High Voltage test; Application guide for measuring devices	IEC 60060-4
Insulation co-ordination	IEC 60071
Insulated Bushing for rated Voltage above 1 kV	IEC 60137
Semiconductor converters. Requirements and commutated converters by network. Part 1-3: Transformers and reactors	IEC 60146-1-3
Low Voltage Switchgear Circuit Breakers	IEC 60157
Testing of insulating materials for interior and exterior, ceramic or glass for systems with a nominal voltage above 1000 V;	IEC 60168
Conductor of Insulated Cables	IEC 60228
Electrical relays;	IEC 60255
Electrical measuring equipment with direct acting records and their accessories	IEC 60258

Standard	Standard Code
High-voltage switches. Part 1: Switches for rated voltages above 1 kV and under 52 kV	IEC 60265-1
Dimensions of Indoor and Outdoor Post Insulators and Post Insulator Units for Systems with Nominal Voltages greater than 1000 V	IEC 60273
Electric cables - Calculation of current rating - art 1-1:	IEC 60287-1-1, 1-2, 1-3
Electric cables - Calculation of current rating - Part 2-1: Thermal resistance - Calculation of thermal resistance Part 2: Thermal resistance - Section 2: calculation of coefficients for reducing the current carrying capacity for groups of cables in the open air and protected from direct sunlight	IEC 60287-2-1, 2-2
Electric cables - Calculation of current rating - Sections on operating conditions - Reference operating conditions and selection of cable type Part 3: Sections on operating conditions - Section 2: Economic optimization of core sections of power cables Part 3-3: Sections on operating conditions - Cables crossing external heat sources	IEC 60287-3-1, 3-2, 3-3
Insulating oils for transformers	IEC 60296
Dimensions of mechanical structures of the 482.6 mm (19 in)	IEC 60297
Loading guide for power transformers immersed in oil	IEC 60354
Locking Devices for Ball and Socket Couplings of String Insulator Units – Dimensions and Tests	IEC 60372
Sulfur Hexafluoride	IEC 60376
Insulators for Overhead Lines with a nominal Voltage above 1000 V	IEC 60383
General Test for Electro-heating Equipment	IEC 60398
Power Cables from 1 kV to 30 kV	IEC 60502

Standard	Standard Code
tests under artificial pollution on high-voltage insulators	IEC 60507
Degrees of protection provided by enclosures (IP code	IEC 60529
Sampling Rules and Acceptance Criteria when applying Statistical Control Methods for Mechanical and Electromechanical Tests on Insulators of Ceramic Material or Glass for Overhead Lines with a Nominal Voltage greater than 1000 V	IEC 60591
Environmental conditions :Specifications for painting	IEC 60721
Electromagnetic compatibility	IEC 61508-3
Test methods for evaluating resistance to tracking and erosion of electrical insulating materials used in harsh environments, ac systems	IEC 60587
Insulating materials based on ceramic or glass - Part 1: Definitions and classification;	IEC 60672-1
Residual strength of string insulator units of glass or ceramic material for overhead lines after mechanical damage of the dielectric	IEC 60797
Railway applications - Supply voltages of traction network systems	IEC 60850
Guide for selection of insulators in pollution	IEC 60815
Testing of power cables (voltage of 30 kV to 150 kV);	IEC 60840
Preparation of block diagrams for control systems	IEC 60848
Control equipment and systems – General principles- Power supply and environment conditions– Interfaces (electrical characteristics) – Performance requirements– Transmission protocol	IEC 60870-1-1, 2-1, 3, 4, 5
Functional safety of electrical/electronic/programmable safety-related systems. Part 3: software requirements	IEC 61000

Standard	Standard Code
Composite insulators for AC overhead lines of nominal voltage above 1000 volts. Definitions test methods and acceptance criteria;	IEC 61109
Railway applications - Fixed installations - Part 1: protection measures in relation to electrical safety and earthing- Part 3-1: Measurement, control and protection for specific use in systems AC drive - Application guide	IEC 62128-1 & 3-1
Railway applications - Fixed installations - Particular requirements for ac devices - Part 3-2: Measurement, control and protection for specific use in traction systems AC - Single phase current transformers	IEC 62128-3-2
Railway applications - Fixed installations - Particular requirements for ac devices - Part 3-3: Measurement, control and protection for specific use in traction systems AC - Single phase inductive voltage transformers	IEC 62128-3-3
High voltage circuit breaker for alternating current	IEC 62271-100
Alternating current disconnectors and earthing switches	IEC 62271-200
Power Transformer	IEC 60076
Instrument Transformer	IEC 60044
Tap changers	IEC 60214
PVC insulated electric cables	IEC 60502
Code of practise for electrical maintenance and supervision of mineral insulating oil in equipment	IEC 60422
Oil impregnated paper insulated condenser bushings	IEC 60137

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 11
SIGNALLING & TRAIN CONTROL AND COMMUNICATION SYSTEM

11 SIGNALLING & TRAIN CONTROL AND COMMUNICATION SYSTEM

11.1 INTRODUCTION

The Chapter provides the main design features of the Signalling & Train Control and Communication System for the operation of SilverLine. Also the associated Sub-Systems according to the requirements of the SilverLine, taking into account the proven of Asian and European systems.

The Signalling & Train Control and Communication system shall provide the highest security level an efficient train control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.

High speed has proven to be a very flexible and attractive system that can be developed under various circumstances in different contexts and cultures. This is the result of four very important characteristics offered to customers and society:

- Safety,
- Velocity,
- Capacity
- Sustainability.

As a result, HSR is a rapidly expanding new transport mode, often described as the “transport mode of the future”.

High Speed Rail is completely a new field for Indian Railways and requires the understanding and adopting of much different specifications and standards rather a completely new technology for construction and maintenance. This chapter is a study of the available literature and information available on the high speed railway systems in the world, the technology adopted by them, and identifying the appropriate parameters, adoptable for semi/high speed corridors in India.

For the speeds of above 200 km/h, the infrastructure can be categorized in “High-Speed” if the system in operations, complies with:

- Track equipment,
- Rolling stock (generalisation of trainsets),
- Signalling systems (abandonment of trackside signals),
- Operations (long-range control centres),
- Geographical or temporal separation of freight and passenger traffics,
- and more globally with the standards for High Speed.

As a guided system, rail is well-suited for speed since the direction of the vehicle is controlled by the rails. The downside of this is that trains cannot avoid obstacles by swerving right of left, like a car, or by changing altitude, like an airplane. Therefore, the track in front of the train must be totally clear of any obstacle.

The specific role of the Signalling & Train Control and Communication systems is to prevent collisions and/or accidents between trains or between a train and an obstacle. In principle, a train can proceed only when the track ahead is free of other trains/vehicles/obstacles over a distance equal to or longer than its braking distance. This role is currently undertaken by signalling posts spread along the side of the track. However, this solution does not suit high speed operation because drivers would not be able to see the signals in due time because of the speed. Instead, all the required information, once delivered by light signals, must be transmitted to the driver’s cab by on-board command and signalling equipment.

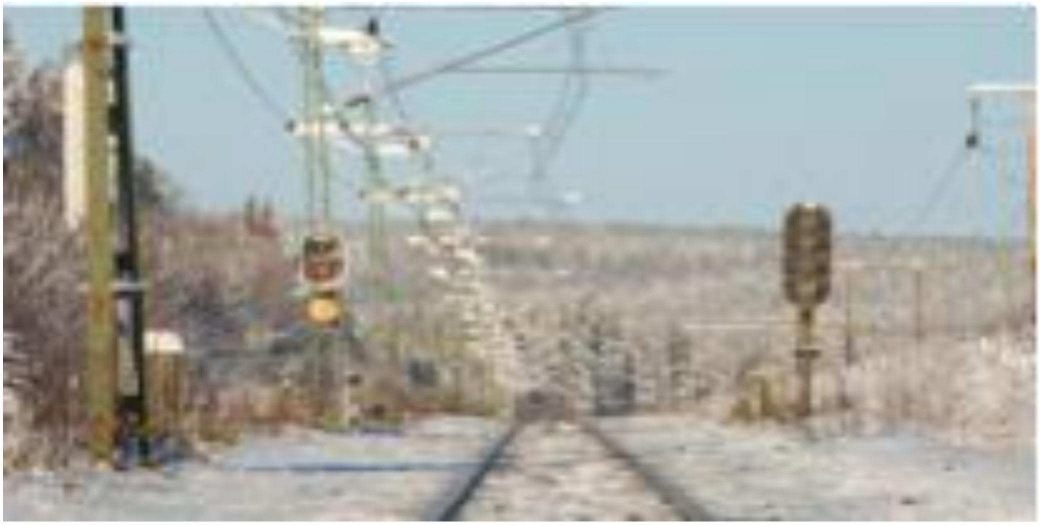


Figure 11-1: Classic Line

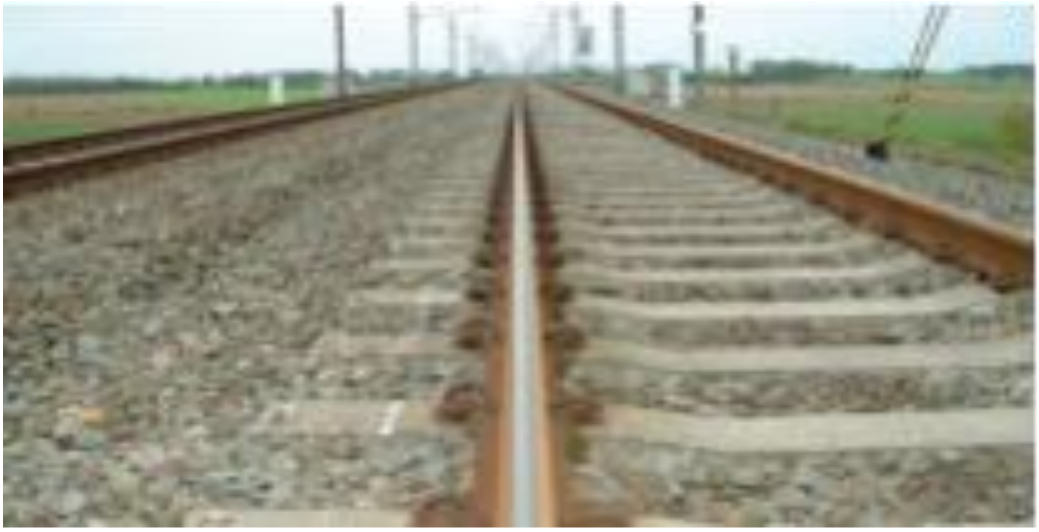


Figure 11-2 : High Speed Line

In the past, almost every country who is operating high speed trains developed its own Signalling and Traffic Control system. Now some universal norms and standards are enforced & focusing on :

- Interoperability,
- Safety,
- Capacity,
- Availability Cost-effectiveness,
- Less on-board equipment open market.

There are mainly two types of Signalling & Train Control systems presently in service for High Speed Rail (HSR):

- ERTMS is known as the European Rail Traffic Management System. ERTMS is divided into levels by function. Europe is shifting towards ERTMS Level 2 on high speed lines and is becoming the standard in Europe. This is true for some Non-European countries also. In HSR lines Radio based Signalling& Train Control system has become the world wide agreed standard for new lines and facilitates the interoperability with neighboring railway networks using different signalling systems as well as it simplifies the driver environment.
- Several countries (South Korea, Germany, China, Japan, etc.) are using their specific system without interoperability. Several countries, where operations started before the ERTMS implementation, are still using and even implementing on new sections of lines the previous proven Signalling & Train Control systems such as ATC, TVM430 or LZB.

Any of these systems can be deployed on a high speed line in order to have Centralized Train Control System. All are Continuous data transmission, allows better performance as it provide updated Signalling & Train Control information real time.

11.1.1 Signalling System in Indian Railway

The Signalling system available in Indian Railway at the speed of 160 kmph and above are mentioned in Table 11-1.

Table 11-1: Existing Indian Railway Signalling System

S. No	Signalling System	Operating Speed	Section/ line
1	ETCS level- 1 with ATP	Upto 160 kmph	Agra-Delhi section 200 km, Chennai Suburban railway section 117 km and Kolkata Metro section 25 km

S. No	Signalling System	Operating Speed	Section/ line
2	Automatic Signalling system with EI	Upto 160 kmph	Indian railway main line network in India
3	Digital ATC with LCK	Upto 320 kmph	Mumbai -Ahmedabad High Speed Rail Line (In execution stage)
4	CATC with Tetra Radio System	Upto 160 kmph	Delhi-Meerut (RRTS) Line (In execution stage)

For the train operations beyond 160 kmph, the Signalling and Train Control system requirement becomes still more stringent due to the fact that above 160 kmph speed it is not possible for the driver to continuously watch the line side signals and also the response time of Signalling Train Control system becomes important. The Cab signalling system is essential for high speed rail at 200 kmph.

Indian Railway taking quantum jump with Long Term Evolution (LTE):

LTE is a next-gen communications network dedicated for railway services, enabling high-speed wireless voice and data communications inside trains, from the train to the ground and from train to train. This network supports voice communication among drivers, control centre operators, maintenance and other railway staff supporting; push-to-talk group communication, broadcasting, location-dependent addressing and multilevel prioritization; data communication for the train control signalling and other operation and maintenance as well as text messaging during voice communication; multimedia communication for wireless video surveillance, mobile video conference, file sharing, mobile office and passenger infotainment services.

Till now Global System for Mobile Communications - Railway (GSM-R) has been the standard for digital railway communications. But with the forecasted obsolescence of GSM-R technology in 2025, Railways are migrating to LTE-R as the new standard.

LTE-R when compared to GSM-R offers several advantages, like low latency, higher data capacity and high security. LTE-R can also support passenger information applications, closed-circuit TV (CCTV), traffic management, ticketing and other services on a single network. In addition to the above, Indian Railways are processing to execute ETCS Level-2 signalling system with LTE in four different sections over Indian Railways. However, this work in under tendering stage now.

Details of Indian Railway- Pilot Projects with ETCS level-2 with LTE (Trail) are mentioned in Table 11-2.

Table 11-2: Pilot Project of Indian Railway

Project Line / Section	Project Length (RKM)	No of Station	Estimate Cost (Railway) of Project (Cr.)
Renigunta-Yeraguntla (South Central Railway)	165	23	483
Nagpur – Budnera (Central Zone Railway)	175	28	478
Jhansi – Bina (North Central Railway)	155	20	489
Vijaynagaram – Palasa (East Coast Railway)	145	14	396
Total Cost	640	85	1846

During the discussion with leading signalling manufacturers Like – M/s Siemens, Hitachi- Ansaldo, Bombardier, Alstom etc. while DPR preparations, they have also indicated that LTE system is latest evolving technology in high speed rail communication system.

LTE (Long Term Evolution) based Mobile Train Radio Control system with ETCS Level-2 system is still on trial in some railways in the world. LTE based ETCS - Signalling Train control System has not come to full-fledged proven certified system. Depending upon the trial results, IR will decide whether to extend ETCS to other lines.

If LTE system does not mature and is not fully accepted worldwide for high speed rail system, by the time of SilverLine project work is executed in Kerala, GSM-R can be considered instead of LTE-Mobile Train Radio Control system. ETCS Level-2 with GSM-R can be adopted at the time of executing this project.

11.2 INTRODUCTION OF SIGNALLING & TRAIN CONTROL SYSTEM

The Signalling & Train Control system shall provide the highest security level to ensure that the operational activities are developed following strict safety requirements. At the same time, it shall meet the requirements for efficient train operations and high quality of service. It assists in optimization of rail infrastructure investment and running of efficient train services on the network. For the High-Speed Rail corridor, the system requires the following minimum facilities:

- Highest security level to ensure the operational activities
- Ensuring safety in train movements
- High quality of service

- Real Time Multimedia information to control room

The high speed train operation requires the deployment of a high speed Automatic Train Control (ATC) system that supports the performance goals of any high speed project, including maximum speeds, trip times, headway and which meets UIC mandated practices and functions for signalling system including High Speed Automatic Train Control. The ATC system with the dynamic speed profile used on high speed rail lines all around the world are:

- ETCS Level -2 (European System)
- Digital -ATC (Japanese System)
- CTCS Level-3 (Chinese System)
- TVM-430 (Transmission Voie-Machine) -French System
- LZB (Linienzugbeeinflussung)-German System

The control-command and signalling subsystem shall provide the means of an efficient train control, ensuring safety in train movements and meeting the expected operational activities in terms of availability and reliability. Below are given some available technologies that are in compliance with lines operated between 300 km/hr and 320 km/hr.

Europe and many Non-European countries are shifting towards ETCS level 2 on both classical and high speed lines as this radio-based signalling system has become the world-wide agreed standard for new lines and facilitates the interoperability with neighbouring railway networks using different signalling systems as well as it simplifies the driver environment.

The ETCS is an initiative backed by the European Union to enhance safety, increase efficiency of trains and enhance cross-border interoperability of rail transport in Europe by replacing signalling equipment with digitized mostly wireless versions and by creating a single Europe-wide standard for train control and command systems.

When a single system is chosen and no additional one is going to be required, there is no need for interoperability and the choice is open. Several countries (South Korea, Germany, China, Japan, etc), are using their specific without interoperability. Several countries, where operations started before the ETCS implementation, are still using and even implementing on new sections of lines the previous proven signalling systems such as ATC, TVM430 or LZB.

No single standard is available for signalling system for High-Speed rail line operation in the world. The signalling system shall provide the means of an efficient train control, ensuring safety movement and meeting the expected operational activities in terms of availability and reliability. Any of the above proposed systems are proven and can be deployed on the high-speed line in order to have a centralized traffic control (CTC) System.

11.2.1 Principle of Signalling System

The Signalling system shall ensure the safe operation of all rail vehicle movements on the Main Line and on all other equipped tracks. It shall meet the operational journey time objectives as stipulated in the Operation Plan. The train control and monitoring is ensured from CTC located in the OCC.

Signalling system shall be designed based on a fail-safe philosophy meaning that any failure will maintain or place the equipment into a safe or more restrictive state. So, no significant failure modes will result in limiting or reducing the safe condition.

To protect against unsafe or conflicting train movement, Electronic Interlocking (EI) system are provided as fail-safe means to authorize train movement during normal and degraded operation. EI system are of distributed type. Wayside equipment (detection system such as axle counters) is connected to the interlocking by secure links and in the same way to ensure safe train movements. Wayside warning systems are connected to the signalling system.

The Signalling system shall comprise a number of primary subsystems/facilities, which include:

- Centralized Traffic Control system (located at the OCC)
- Back-up OCC
- Depot Control Rooms (DCR) at each Depot
- Train detection system (as axle counters) on the mainline and in depots
- Electronic interlocking system
- Protection against unauthorized movements on to the High-Speed Rail Line.
- Cab Signalling System incorporating Automatic Train Control (ATC) for mainline
- Wayside Signalling system (for tracks inside the depot)
- Track Safety Protection System (TSP) for the protection of staff working on the mainline and on depots

For normal operation and depending on its location, the HSR is controlled from several signalling centres as follows:

- The CTC controls the Main Line, covering all train movements on the HSR, and access to and from depots. The OCC combines the CTC of the Signalling and Communications Systems, plus the Electrification System control facility, and warning and protection systems. The CTC remotely controls all the mainline interlocking via a Telemetry System, using duplicated links for availability.
- All interlocking stations having points and crossings is provided with workstations (VDU-Local Control Panel) for local control in Station Control Room (SCR). The station and yard layout will be clearly indicated on workstation (VDU) with position of points, track detection system etc. The

setting of the route and clearing of the signals will be done by workstation, which can be either locally (at station) operated or operated remotely from the OCC. It will be possible to operate the workstation locally, if the central control hand over the operation to the local station. Also, communication facilities should be provided at each SCR for communication with OCC, local authorities and adjacent station etc. The workstation for local control (at SCR) should be provided at each interlocking station for operation in case of emergency.

- A back-up CTC is provided to cope with the case of failure or unavailability of the OCC, as well as serving as emergency management room.

The Depot Control Room (DCR) controls the wayside signals within each depot. The normal method of train control on the mainline shall be by Cab signalling. Movements between depot entrance/exit roads and the mainline (and vice versa) are also controlled by the cab signalling system. Shunting movements within the Depots shall be controlled by Wayside signals. To maximise usage of any double track between the Main Line and Depots, normal running shall be provided on both lines in both directions. The system of communication between track and train shall ensure that data capacity and exchange rates are sufficient to guarantee the specified signalling Headway and capacity requirements.

The signalling arrangements shall be designed and constructed to achieve an Operational Headway sufficient to achieve the Operation Plan. Signalling arrangements shall permit running at the maximum Line Speed in both the Normal and Reverse directions. Each line throughout any section of the Main Line shall be capable of changing to Reverse direction operation independently of all other lines, including adjacent lines. This arrangement shall therefore permit overtaking movements to be made. Transfer to and from the Reverse direction track shall be achieved by signalled moves over crossovers connecting the running lines, normally in a facing direction. However, it shall be possible to make “setting back” moves under full Cab signalling control.

11.2.2 Cab Signalling

For train operations beyond 160 kmph, the Signalling and Train Control system requirement becomes still more stringent due to the fact that above 160 kmph speed it is not possible for the driver to continuously watch the line side signals and also the response time of Signalling Train Control system becomes important. It is necessary to improve the safety level & to ensure the safety of train movements. Overlooking a wayside signal may cause a serious accident when high speed trains with more than 200 kmph runs. The Cab signalling system is essential for high speed rail at 200 kmph.

The Cab Signalling system shall provide full and complete in-cab information to the driver to permit interpretation of signalling and permitted speed conditions together with a direct link to the train braking system to automatically enforce train braking in the event of excess speed. The Cab Signalling system shall be capable of dealing with all classes of route (Main/Shunt/Call-on Route) required. The Cab Signalling system shall be designed and configured to permit smooth and efficient service braking applications.

When traversing permanent or temporary speed restrictions the train speed shall be restricted for the length of the PSR or TSR only, taking due account of train length. Trains shall not be restricted unnecessarily under such conditions. To cope with failure, a degraded mode of operation is available, with Wayside route indications for use at low speed.

The Cab Signalling system shall be designed for Bi-Directional operation and shall provide comprehensive speed supervision incorporating, but not limited to, the following:

- Utilization of predetermined braking curves
- Monitoring of signalling and other speed limiting conditions
- Computation of permitted speed
- Continuous monitoring of actual train speed
- Continuous comparison of actual speed with permitted speed
- Automatic application of braking in the event of excess speed above a margin.

Cab Signalling may be based on a fixed or moving block system. In determining the level of proceed authority to be given to a train, the system shall take into account all relevant data including, but not limited to:

- Location of train and Stopping points
- Condition of block sections ahead
- Interlocking conditions
- Permanent and Temporary speed restrictions
- Track safety protection zones
- Type of route which has been set
- Gradients information
- Rolling stock characteristics

Information given via the driver’s interface together with Wayside indicators or markers, as required, shall form a comprehensive Signalling System enabling trains to be moved safely and efficiently up to the full capacity of the line.

Detection of irregular wrong direction movement of a train set by the Cab Signalling System is required and shall result in an emergency brake application and associated alarm being given to the driver.

Under certain operational conditions such as emergencies, train failures, signalling failures etc., it will be necessary for trains to pass Stopping Points under safe working procedures. The Cab Signalling system shall facilitate such operations and provide the following details:

- Means by which the driver may override the cab signalling system
- Permitted speed under emergency and failure condition.
- Distance to next target
- Action at next target
- Transition back to normal operation

The cab-signalling system shall be able to trigger a Trip mode when a restrictive state signal is sent by the ETCS ground. When switching to Trip mode, the train shall operate an emergency brake to stop the train. The Post Trip mode transfer must be immediate after acknowledgment by the agent driving the train stopped following an emergency crossing (train trip). Then the driver must be able to release the emergency brake. ETCS on-board equipment should provide the function for the train driver to restart or switch to shunting mode.

11.2.3 Standardization of Train Control System

High-Speed Rail (HSR) Signalling systems is a type of rail transport that operates significantly faster than traditional system. New trains lines having speeds in excess of 250 kmph and existing lines in excess of 200 kmph are generally considered to be high speed.

The countries like South Korea, Germany, China, Japan etc are using their specific Signalling & Train Control system without interoperability. Several countries, where operations started before the ETCS implementation, are still using and even implementing on new sections of lines the previous proven Signalling Systems such as ATC, TVM430 or LZB.

Presently, almost all trains in Europe operate at speeds upto 200 kmph. European countries are shifting towards ETCS Level 2 on high speed lines and is becoming the standard in Europe. This is true for some Non-European countries also. In HSR lines, radio-based signalling System has become the worldwide agreed standard for new lines and facilitates the interoperability with neighbouring railway networks using different signalling systems as well as it simplifies the driver environment.

Among other key benefits of ETCS level 2, it is the only rail control system able to raise a complete railway network to another level as a continuous communication-based solution.

Advantages of ETCS as below:

- Increased capacity on existing railway lines.
- Greater ability to respond to and satisfy the growing passenger and freight transport demands.
- ETCS level-2 reduces headway between trains enabling up to 40% more capacity on the currently existing infrastructure.
- Higher speeds: ETCS Level-2 allows for a maximum speed of up to 350 km/hr and is now considered in several countries as the system of choice for the construction of new High-Speed lines.
- Higher reliability rates: ETCS Level-2 helps to significantly improve reliability and punctuality, which are crucial for both passenger and freight transport.
- Reduced maintenance costs where Trackside signalling equipment is no longer required and therefore reduced Capital expenditure.
- An open supply market: Trackside and on-board equipment may be supplied by any of the ETCS suppliers as all equipment is fully interoperable, making the supply market more flexible, independent and competitive.
- Having a worldwide accepted and maintained a series of technical standards brings significant economies of scale and competitive whole life cycle costs.
- Improved safety for passengers, employees and freight transport, which may be an issue in certain parts of the world.
- Full network interoperability nationally and internationally.

ETCS level-2 is recommended because of its continuous Automatic Train Protection and moving block sections that are providing a continuous transmission of MA (Movement Authority). Vital information exchanged between mobiles and wayside is transmitted by secured radio. This system is currently used or under implementation in whole Europe as well as in South Korea, Saudi Arabia, Taiwan and UAE for conventional and HS Lines. This signalling system is designed for all types of lines, but it is especially interesting for HSL because the driver does not have sufficient time to react after observing lineside signals at very high speed and the wayside equipment transmits information to the train to perform Automatic Train Protection (ATP) and to display the necessary driving information in the driver cab.

Currently, 50% of the global signalling market share is based on ETCS technology with more than 50 countries deciding to deploy or already committed to ETCS. ETCS investments by non-European countries represent more than 50% of the global ETCS investment worldwide. Increasing investment on ETCS has been witnessed in China, India, South Korea, Taiwan, Saudi Arabia, UAE, Morocco, Algeria, Turkey, Kazakhstan, Indonesia, Brazil, Mexico, Australia and New Zealand.

ETCS projects are underway in Europe and also outside Europe. The three largest installations of ETCS outside Europe will be China, Saudi Arabia and Turkey. Other major countries such as Australia, Argentina, Morocco and even USA is also showing interest in this technology, with several pilot lines planned in different countries.

ERTMS System (ETCS Level-2 with GSM-R) system is the current "State of the art system" and has become the international standard that can be provided by different European and Asian suppliers. ETCS Level-2 has now become a worldwide standard and a technological success.

The command and control subsystem chosen, which is a standardized, interoperable ATP/ATC system called ERTMS/ETCS (or simply ETCS).

- ERTMS, refer to the whole standard programme or railway platform
- ETCS, refer to the Signalling System, component of ERTMS
- GSM-R, refer to the Global mobile radio system (Data & Voice), component of ERTMS

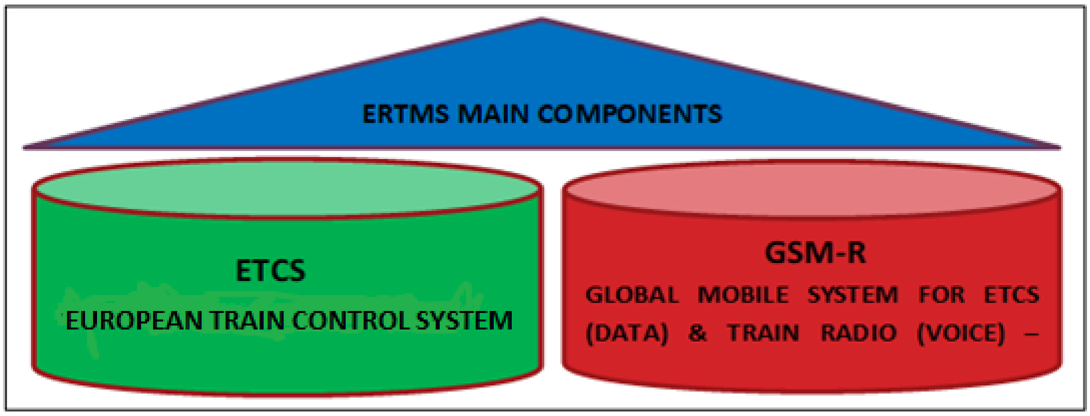

ERTMS MAIN COMPONENTS
ETCS
EUROPEAN TRAIN CONTROL SYSTEM
GSM-R
GLOBAL MOBILE SYSTEM FOR ETCS
(DATA) & TRAIN RADIO (VOICE) –

Figure 11-3: ERTMS Components

- **ETCS (European Train Control System)** - the signalling element of the system which includes the control of movement authorities, automatic train protection and the interface to interlockings. It allows the stepwise reduction of complexity for train drivers (automation of control activities), It brings track side signalling into the driver cabin, it provides information to the onboard display, It allows for permanent train control, Train driver concentrates on core tasks.

- **GSM-R (Global System for Mobiles - Railway)** - the communication element containing both a voice communication network between driving vehicles and line controllers and a bearer path for ETCS data. It is based on the public standard GSM with specific rail features for operation e.g. Priority and Pre-emption (eMLPP), Functional Addressing Location Dependent Addressing, Voice Broadcast Service (VBS),Voice Group Call (VGC), Shunting Mode, Emergency Calls, General Packet Radio Service (GPRS option),Fast call set-up.

LTE-R, which could be based on the LTE standard, is a likely candidate to replace GSM-R in the future. To handle increasing traffic, ensure passenger safety, and provide real-time multimedia information, a new communication system for HSR is required. In the last decade, public networks have been evolving from voice-centric second-generation systems, e.g., Global System for Mobile Communications (GSM) with limited capabilities, to fourth generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability.

LTE-R, which could be based on the LTE standard, is a likely candidate to replace GSM-R in the future for the following reasons:

- LTE has many advantages over GSM in terms of capacity and capabilities.
- As a fully packet-switched-based network, LTE is better suited for data communications.
- LTE offers a more efficient network architecture and thus has a reduced packet delay, which is one of the crucial requirements for providing ETCS messages.
- LTE has a high throughput radio access, as it consists of a number of improvements that increase spectral efficiency, such as advanced multiplexing and modulation.
- LTE is also a well-established and off-the-shelf system and provides standardized inter working mechanisms with GSM.

GSM-R is built on the proven GSM standard for cellular wireless communication. This means that all sorts of existing hardware can be easily modified by vendors and manufactures in order to work on the LTE platform.

The World’s First LTE-R system for 250 kmph high speed railways was implemented in Republic of Korea on new line Wonju- Gangneung on 21st December 2017, Line operated by the Korea Rail Network Authority (KRNA), spans 120 km long. LTE-R wireless communication System was used for Train Operation and maintenance. Frequency allocation for this project was 700 MHz bands (UL-718-728 MHz and DL 773-783 MHz). LTE-R system supports railway specific wireless service (Voice, Video, Large Data) between stations and trains based on 4G Technology LTE.

The Korea Railway verification of 23 test items at Test- Bed on KTX Honam Line (34.3 km, Iksan to Jeongeup including Noryeong Tunnel 4.3 km). The Standardization of the LTE-R standards for Conventional and High -Speed rail service with Telecommunications Technology Association (TTA) in Korea.

11.2.4 European Train Control System (ETCS)

ETCS (European Train Control System) is the Train -Control element which includes Automatic Train Protection (ATP). ETCS works on the principle of providing to the train a maximum distance that it can travel, the speed profile of the track ahead and other track information about the route that has been set. The train permits the driver to drive the train but should the distance or speed limit to be exceeded, or be in danger of being exceeded, then the ETCS on board equipment intervenes to control the train, bringing it to standstill if necessary.

ETCS is not a signalling system in and of itself. Along with other items, it forms part of signalling system. The signalling element of the system which includes the control of movement authorities, automatic train protection and the interface to interlockings. It allows the stepwise reduction of complexity for train drivers (automation of control activities) - It brings track side signalling into the driver cabin - It provides information to the onboard display - It allows for permanent train control - Train driver concentrates on core tasks.

ETCS Benefits are:

- **Increased capacity:** As a continuous communication-based Signalling system
- **Higher Speeds:** Allows for a maximum speed up to 350 kmph
- **Higher reliability rates:** May significantly increase reliability and punctuality
- **Lower production costs:** Proven, harmonized system is easier install, maintain
- **Reduced Maintenance costs:** ETCS Level-2, Trackside Signalling is optional

11.2.5 European Train Control System (ETCS) Levels

European Train Control System (ETCS), is an Automatic Train Protection (ATP) system to replace the existing national ATP system. ETCS is divided into different functional level (to match customer’s needs). The definition of the levels depends on how the railroad is equipped and the way in which information is transmitted to the train.

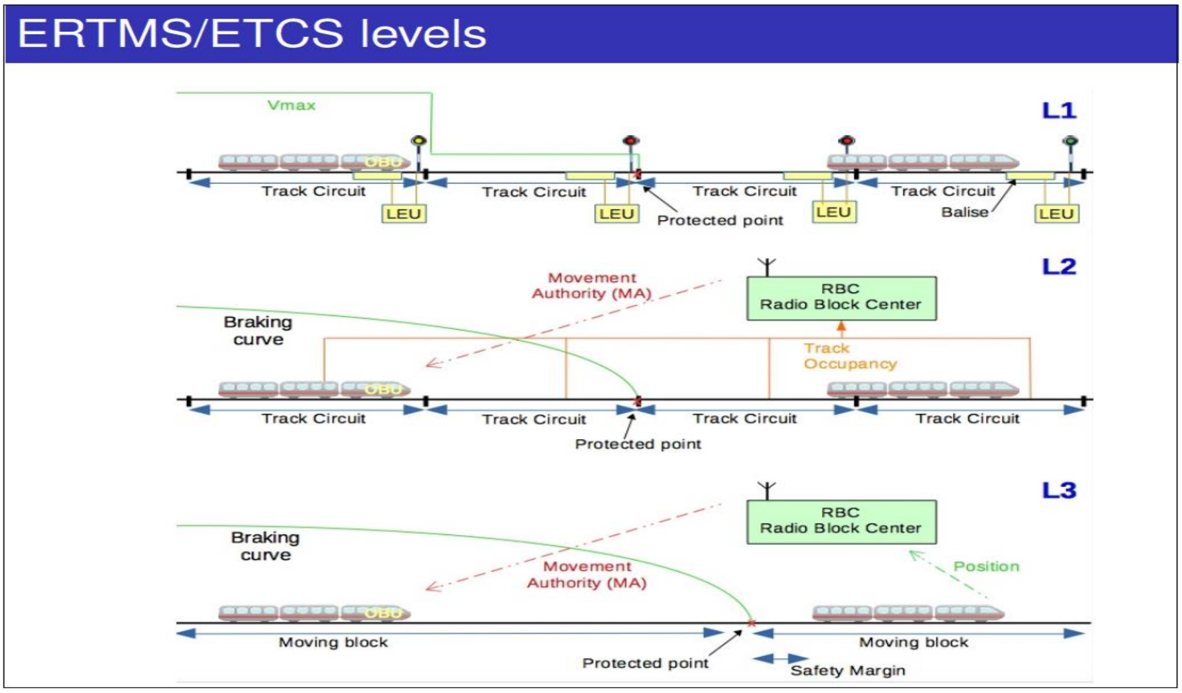


Figure 11-4: ERTMS/ETCS Levels

Train Control System is the core signalling and train control component of European Rail Traffic Management System (ERTMS). ETCS continuously calculates a safe maximum speed for each train, with cab signalling to the driver and on-board systems that take control if the permissible speed is exceeded. For ETCS- Trackside equipment and train borne systems need to be standardized according to the different ETCS levels.

11.2.5.1 ETCS Level- 1

ETCS level -1 is a cab signalling system that can be superimposed on the existing signalling system that leaves the fixed signal lateral system (national signalling and track release system) in place. Communication between the tracks and the train is ensured by dedicated Eurobalises located on the track adjacent to the lineside signals at required intervals and connected to the train control centre. Receiving the movement authority through Eurobalises, the ETCS on board equipment automatically calculates the maximum speed of the train and next braking point if needed, taking into account the train braking characteristics and the track description data. This information is displayed to the driver through a dedicated screen (Driver Machine Interface) in the train cabin. The speed of the train is continuously supervised by the ETCS on board equipment.

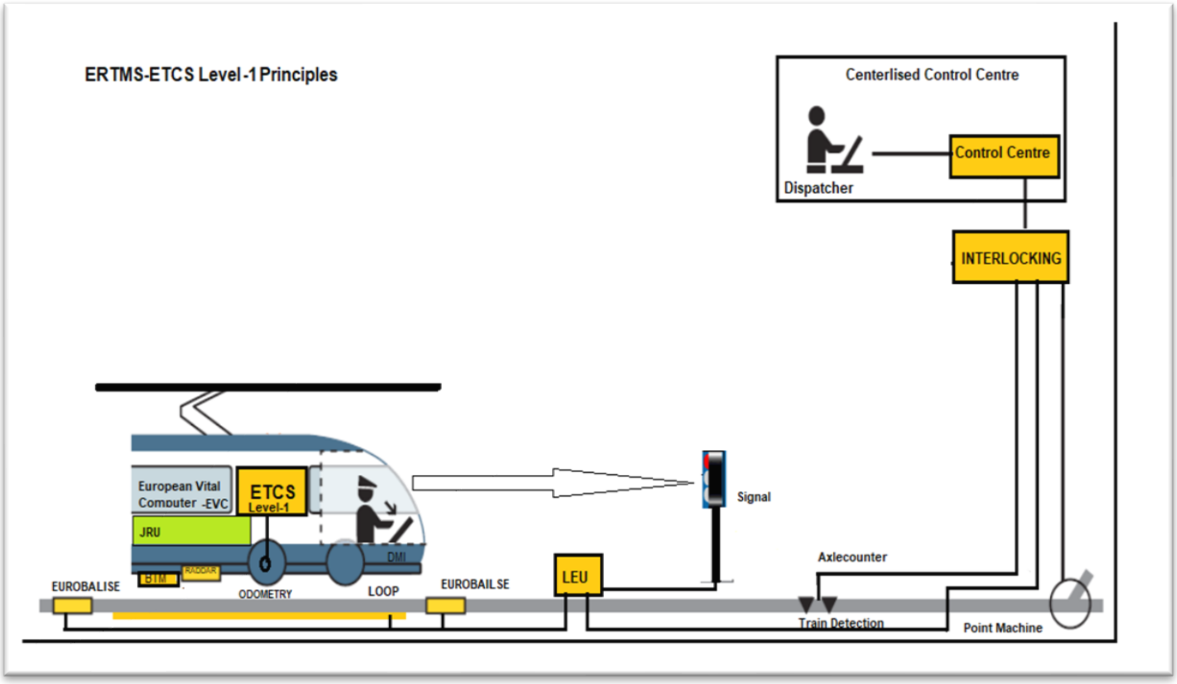


Figure 11-5: Overview of ETCS Level -1 Principles

11.2.5.2 ETCS level- 2

ETCS level-2 is digital radio-based signal and train protection system. The movement Authority is communicated directly from a Radio Block centre (RBC) to the on-board unit using a radio channel (LTE/GSM-R). Movement Authorities are given to the driver in order to allow the train to move itself on the track and most of the signals are displayed in the train borne cab, substituting the lateral traditional signals. Thus, apart from a few indicator panels like overriding and board signals (these panels mark the extreme points of a block section or of the ETCS Level-2 area). It is therefore possible to work without lateral trackside signalling.

The train separation system uses the term Virtual Signal, because the concept of a traditional railway signal, like fixed LED signal, is physically moved to the train DMI (Driver Machine Interface). However, with the track-release signalling devices like Axle counter /track circuits, the train integrity supervision still remains in place at the trackside. All trains automatically report their exact position and direction of travel to the RBC (Radio Block Center) at regular intervals, through the LTE/GSM-R radio network.

The RBC knows from trains their positions, it receives train detection and route status information from the Interlocking and Automatic Block System as applicable and makes information available to each train in the form of movement authorities. Train movements are monitored continuously by RBC. Any movement authority is transmitted to the train continuously via LTE/GSM-R together with speed information and route data.

The Eurobalise are used at this level as passive positioning beacons or electronic milestones. Between two positioning beacons the train determines its position via sensors. The positioning beacons are used in this case as reference points for correcting distance measurement errors. The on-board computer continuously monitors the transferred data and the maximum permissible speed. A continuous stream of data informs the driver of line- specific data and signal status on the route ahead, allowing the train to reach its maximum or optimal speed but still maintaining a safe braking distance factor.

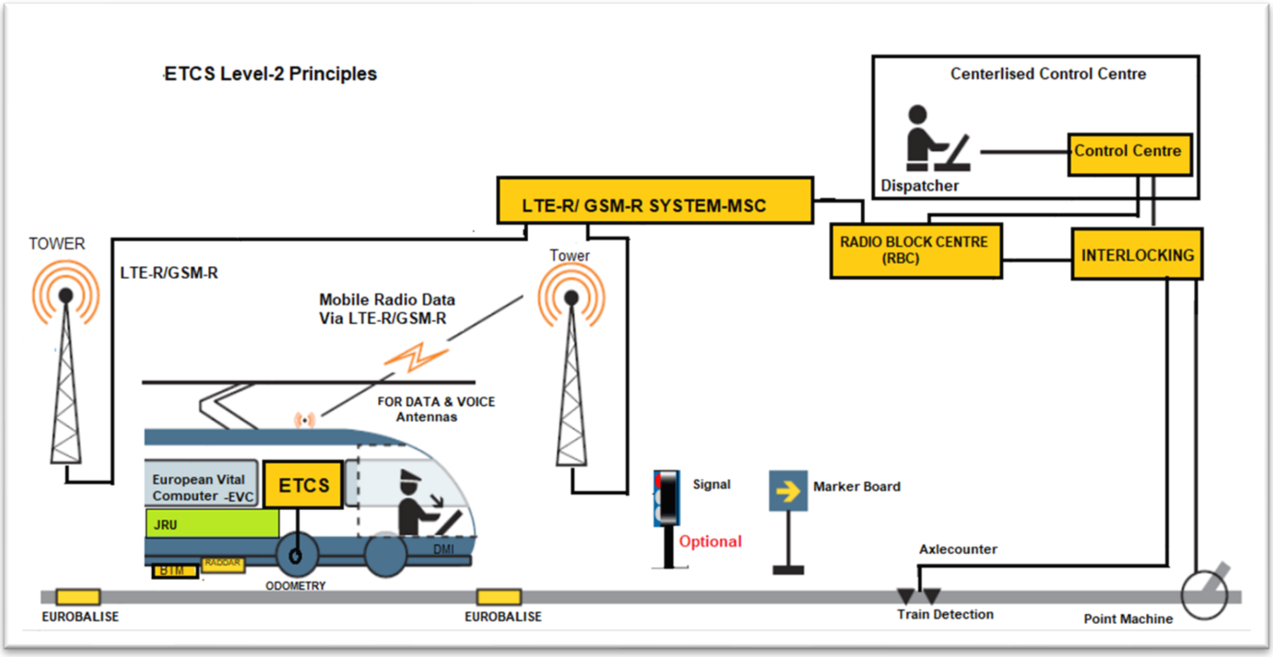


Figure 11-6: Overview of ETCS Level -2 Principles

11.2.5.3 ETCS-Level-3

ETCS level 3, still in its conceptual phase, introduces a “moving block” technology. Under ETCS level 1 and 2 movement authorities are determined using “fixed blocks” section of tracks between two fixed points which cannot be used by two trains at the same time. ETCS Level-3 is a fully radio-based system without any trackside equipment. The Radio Block Center (RBC) receives positioning of each train continuously and calculates the smallest possible train distances at any time. Therefor the track is no longer separated in fixed blocks but split into “moving blocks”. At the same time, it is vital that trains guarantee their integrity as there is no trackside equipment available to provide this information.

As with ETCS Level 2, trains find their position themselves by means of positioning beacons and via sensors and must also be capable of determining train integrity on-board to the very highest degree of reliability. The route is thus no longer cleared in fixed track sections. In this respect ETCS Level-3 departs from classic operation with fixed intervals, because it calculates safe distance between two trains.

A movement authority is given the information relating to the position of the train, based on the actual distance of a train from the next train. This solution, called absolute braking distance spacing or moving block, ensures a greater exploitation of the capacity of the line as it reduces the granularity of the spacing. ETCS Level-3 is currently under development phase and still not standardized.

11.2.5.4 Comparison of ETCS Levels

ETCS has been designed to meet the railway's needs and this is reflected by the different levels available. The existence of other signalling system on the line, the possibilities to equip the line with LTE/ GSM-R technology, the maximum speed allowed, or capacity upgrades are amongst the factors which come into play when choosing a particular ETCS level.

Table 11-3: Comparison of Main Feature of ETCS Levels

Main Features of ETCS Level	On Board Compatibility of System	
	ETCS Level 1	ETCS Level 2
Lineside signals	Applicable	Optional
Track vacancy detection system	Applicable	Applicable
Eurobalise as position markers	Applicable	Applicable
Cab signalling	Applicable	Applicable
Continuous speed monitoring	Applicable	Applicable
Intermittent data transmission	Applicable	Applicable
Continuous data transmission	Optional via Euroloop	Applicable via LTE/GSM-R

However, it is commonly acknowledged that ETCS Level-2 brings the full benefit of the system to a reality, as it allows for increased capacity and significant costs saving for maintenance through the removal of lineside signals.

11.2.6 Architectural Description of ETCS Level -2

High-Speed rail line can be equipped as a complex transport equipment with ETCS level-2 signalling system solution able to control train movements, in order to guarantee the safe and regular traffic operations. ETCS level – 2 on high speed new line is becoming standard in Europe and other Non -European countries also. ETCS level-2 has been designed to be the most performant train control system in the world. ETCS level shall offer considerable advantages in terms of line capacity increase. When using ETCS Level-2, a continuous stream of data informs the driver of line-specific data and signals status on the route ahead, allowing the train to reach its maximum or optimal speed but still maintaining a safe braking distance factor.

The LTE/GSM-R network is used for the communications of bi-directional Voice and Data messages between on-board subsystems and control centre. Continuous data transmission allows better performance than intermittent transmission as it is possible to provide the train with updated signalling information any time and wherever the train is. Based on this information, the on-board system continuously displays the Movement Authority to the driver (cab-signalling principle) and monitors the train speed.

Wayside equipment Euro-balise are used for train location and Radio Block Center (RBC) that elaborate messages sent to the train based on the information received from IXL systems, track detection devices and on the basis of exchanged information with the on-board system. The communication between on-board and wayside equipment is continuous using the LTE/GSM-R network.

The main objective of the exchanged messages is to provide movement authorities to allow the safe movement of trains under the responsibility of the RBC.

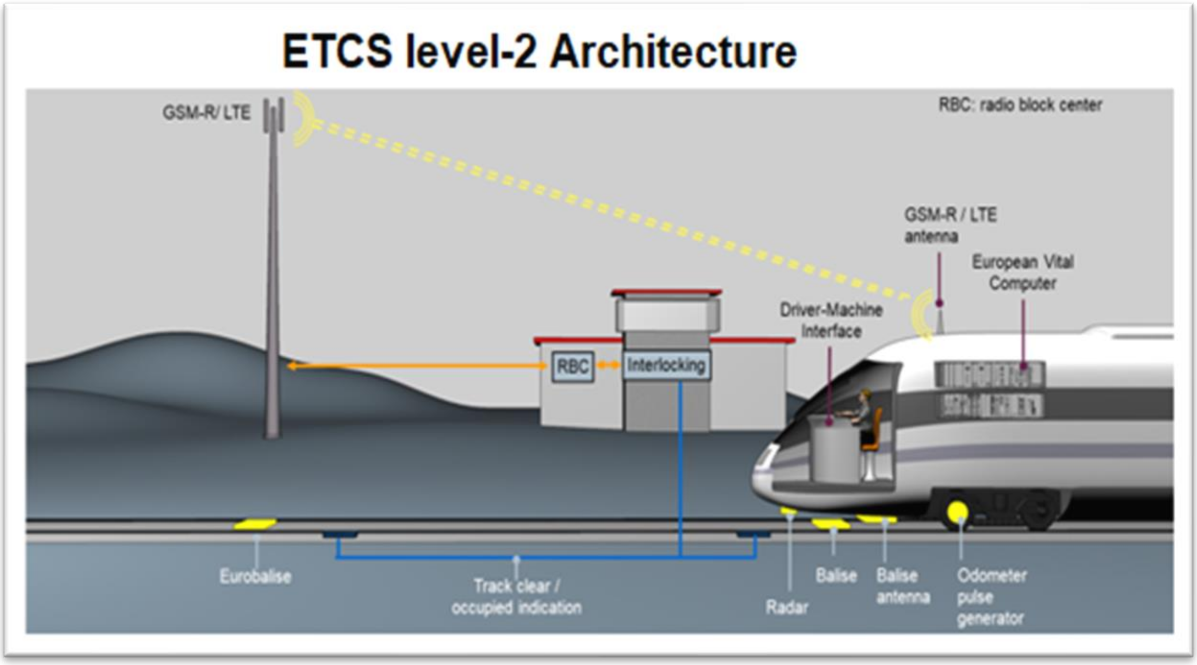


Figure 11-7: Architecture of ETCS Level-2 System

With ETCS Level 2, signalling equipment along the HSRL and in the interlocking cabinets are linked to the Radio Block centres. Information transmitted to the RBC are in relation with the signalling inputs i.e. track occupancy, point positions, speed restriction.

The RBC is in charge to control the trains located in its area. Movement Authorities are transmitted by the RBC to the trains. The RBC memorizes all trains identity and position within its area of responsibility. The Safety Integrity Level (SIL) of the RBC must be SIL4.

The ETCS level-2 is a radio-based train control system interfacing with the interlocking system. The interlocking reports the status of objects controlling the routes of the trains to Radio Block Centre (RBC), which in turn generates the Movement Authority (MA) for the different trains in the section.

Interfaces must be installed at the interlocking equipment in order to send information to the RBC such as point position, track circuit occupancy, routes set etc. in order to allow the RBC to send Movement Authorities (MA) to the ETCS operated trains. The RBC is also interfaced with:

- Adjacent RBC, in order to allow hand over of the train from an RBC to the other.
- LTE/GSM-R Mobile radio for sending messages to the trains
- Computerized systems to help maintainers.

The train transmits its position to the Radio Block Center (RBC) equipment in charge to send Movement Authorities to the train (headway function). Euro-balises with fixed data are installed generally at Markers locations at the beginning of the block sections to reset the on-board odometer.

ETCS Command /Control System ensures the following functions:

- The spacing of trains
- The cab signalling function (display of driving information in the driver cab)
- The supervision (monitoring) of the train speed
- The interlocking (signal boxes) which are required in stations, cross over, sidings for route setting, protection
- The Operation Control Center (OCC) from where the signalling installations along the line are remote controlled.
- The complementary safety systems which include the Hot Box Detectors, the speed limitations systems, the detection of falling vehicles from bridges, the protection of maintenance teams etc.

ETCS Operating Mode-The ETCS on board equipment train can be operated in different operating modes, each of which offer a different degree of supervision and protection. Some important modes are:

- **Full Supervision (FS):** This is the normal mode of operation. Real speed and maximal authorised speed are displayed on the DMI. The on-board supervise the train speed.
- **On Sight (OS):** The On-Sight mode enables the train to enter into a track section that could be already occupied by another train or obstructed by any kind of obstacle.
- **Staff Responsible (SR):** The Staff Responsible mode allows the driver to move the train under his own responsibility in an ETCS equipped area. This mode is used when the system does not know the route for example after a loss of radio contact.
- **TRIP:** The ETCS on-board equipment shall command the emergency brakes in case the train overpasses the End of Authority (no brake release is possible in Trip mode)
- **Over Speed:** In case the train exceeds the permitted speed there is automatic application of the emergency brakes and the driver can take control of the train only when the train speed is inferior to the authorized speed.
- **Speed Restrictions:** All the speed restrictions permanent or temporary are transmitted to the train via the Movement Authority. The on-board system calculate the driving indications to be displayed on the DMI consequently.
- **Shunting (SH):** The driver manually selects Shunting (SH) mode and is now responsible for the movement of the train. It is planned that all propelling moves over uncontrolled or undetected infrastructure in application Level-2 without lineside signals will be made in SH mode.
- **Isolation (IS):** The ETCS onboard equipment can be isolated from the rest of the train’s operating systems and enters Isolation (IS) mode. ETCS provides neither protection nor supervision (including emergency brake intervention) in IS mode. The ETCS onboard equipment can only be brought out of IS mode by a maintenance technician.

ETCS Operational Functions- ETCS provides additional functions to handle specific situations such as:

- Start of mission, to enter the train characteristic, select the mission and the conditions to move the train
- Supervision of inadvertent movements: standstill supervision, rollaway protection, reverse movement protection and backward distance monitoring
- Management of track condition, such as powerless section, non-stopping area (tunnel, bridge, other reasons)

- Override End of Authority, to pass the stop signal in restricted driving conditions after the driver got the permission
- Modification of speed and distance (with limitation) when the driver is responsible for train movement.
- Vigilance control and Manual request for entry or exit shunting operation.

ETCS level 2 requires wayside equipment and on-board equipment. As standards are set, manufacturers can be different.

High speed and high capacity rail line can be equipped with a complex transport system equipped with an ETCS Level-2 signalling system solution, able to control train movements, in order to guarantee the safe and regular traffic operations. The whole ground systems comprise of the of power supply, communication and a ground trackside subsystem with:

- Train control and distance separation subsystem (ETCS)
- Line management subsystem -Interlocking System (IXL)
- Automatic Train Supervision subsystem (ATS)

The On-board/Train borne System comprises mainly:

- EVC (European Vital Computer)
- DMI (Driver Man Interface)
- Odometry subsystem

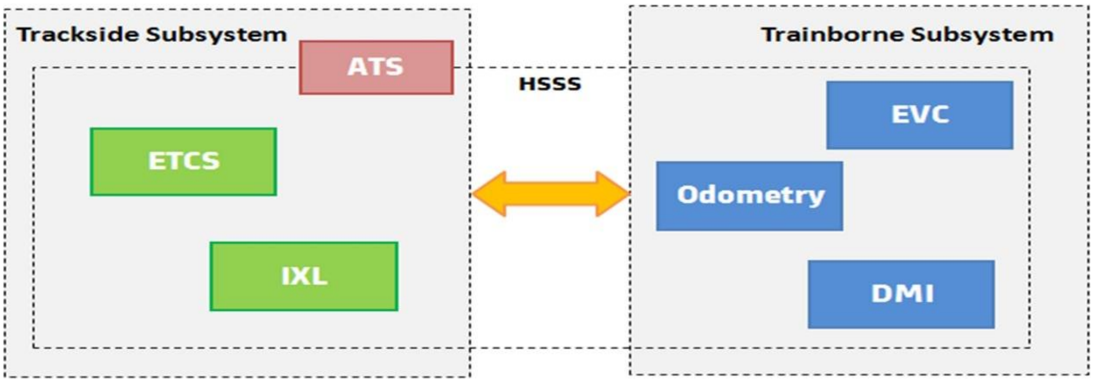


Figure 11-8: High speed /High capacity transport system

ETCS is not a signalling system in and of itself. Along with other items, it forms part of a Signalling system. ETCS is divided into two parts.

- ETCS trackside equipment
- ETCS onboard equipment.

ETCS forms part of a signalling system. Other, conventional signalling, equipment is necessary to form a complete signalling system. Some ETCS Application Levels also use the LTE/GSM-R data radio network to transfer data between ETCS trackside equipment and ETCS onboard equipment. The Conventional signalling equipment includes interlocking, signaller interface, technician terminal, train detection, points, plungers, indicators, and signage. Conventional signalling equipment may also include signals. The supporting equipment is also required to form a complete signalling system and, in some applications, to transfer data between the ETCS trackside equipment and the ETCS onboard equipment.

11.2.7 ETCS Level-2 Trackside Equipment

The main component of ETCS Level-2 of track side equipment is required to send information like movement authority, position of a train and details of track section for running the train safely. Ensure the safe space separation among the trains working on the High-Speed line and Monitor the travel of the train, advising the driver if he passes a red (danger) signal or exceed a speed restriction. In these cases, the system will apply an automatic brake if the driver fails to respond to the warnings.

The main functions performed by the ETCS Trackside/Wayside equipment are:

- Knowing each train equipped with and running under ETCS within an RBC area.
- Following each ETCS controlled train's location within an RBC area.
- Determine movement authorities according to the underlying signalling system for each train individually.
- Transmit movement authorities and track description to each train individually.
- Handing over of train control between different RBC's at the RBC-RBC borders.
- ETCS Level-2 wayside equipment is composed of Euro-balises, RBC and shelters to house devices for connection and power supply.

The main trackside equipment of ETCS Level -2 systems are as below:

11.2.7.1 Radio Block Centre (RBC)

Radio Block Centre (RBC) is a subsystem of ETCS Level - 2 acting as a centralized safety unit. RBC transmits all the information required for a safe run within a particular stretch of track by radio from the interlocking to train. This information is indicated on the cab display system (DMI). For purposes of transmission, the Digital Mobile Radio Communications (LTE/GSM-R) is used. RBC using a radio connection via LTE/GSM-R, receives train position information and sends movement authorization and further information required by the train for its movement. The RBC interacts with the interlocking to obtain signalling-related information, route status, etc. It is also able to manage the transmission of selected trackside data and communicate with adjacent RBC's.

The most important functionality for RBC on ETCS level - 2 is to transmit the movement authority to the onboard unit. RBC continuously received the current process image from the connected interlockings and via radio, sends the movement authority to the ETCS train. The information transmission is made up of the following phases:

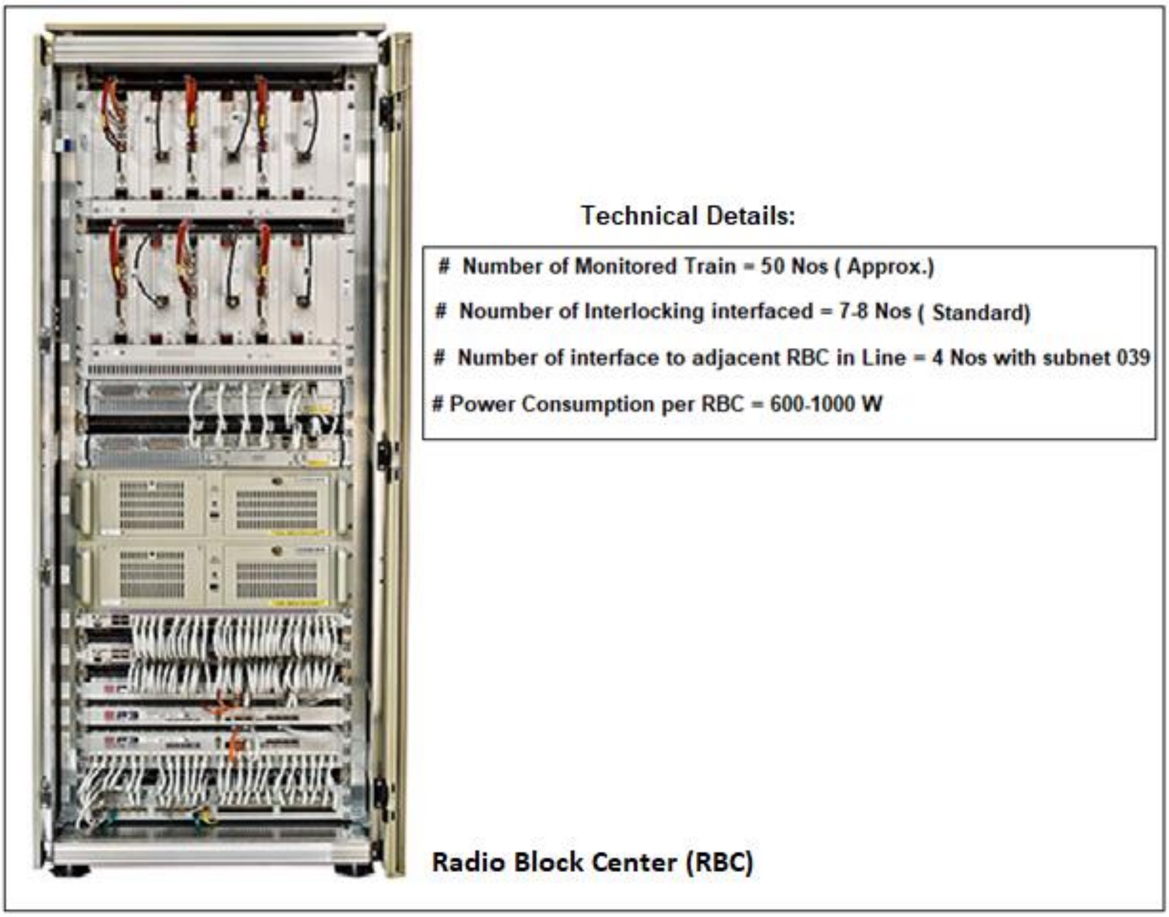
- Interlocking system controls and supervises the trackside equipment and sets the routes according to traffic control requests.
- Interlocking system transmits the information of set routes or elements to RBC.
- RBC calculates the movement authority for each unit according to the information obtained.
- RBC transmits the movement authority to each unit in the RBC area.
- On-board unit calculates the braking curves and supervises the permitted speed.

RBC consists of the following parts:

a) A redundant Vital safety management subsystem, based on proprietary 2-out-of-3 architecture and SIL 4 certified, supporting:
    - Message encryption and decryption, according to Mobile Radio Communication (LTE/GSM-R) specifications
    - Movement Authority Management
    - Human Machine Interface.

RBC may be interfaced using of safety related protocols with both adjacent RBCs and Interlockings, with flexibility on the total number of interfaces. The RBC can even be interfaced directly with the field objects, and so it can perform some of the functionalities traditionally assigned to Interlocking.

b) A redundant Non-Vital management subsystem based on commercial hardware architecture, including:
    - Events recording and diagnostics, connected to the Maintenance Management System
    - Remote supervision and/or CTC interface.



Technical Details:

- # Number of Monitored Train = 50 Nos (Approx.)
- # Noumber of Interlocking interfaced = 7-8 Nos (Standard)
- # Number of interface to adjacent RBC in Line = 4 Nos with subnet 039
- # Power Consumption per RBC = 600-1000 W

Radio Block Center (RBC)

Figure 11-9: Radio Block Center (RBC)

Radio Block Centre (RBC) of an ETCS Level-2 can handle approx. 50 no of trains. Thus, if they’re more than 50 trains (Up and Down included) to be run in between 529.450 km stretch, correspondingly a greater number of RBC would be required with redundant hot standby configuration.

Safety requirements for the interface need to be as high as the requirements to the safety-critical information of interlocking system or RBC. This means that SIL-4 system will be required. RBC is a system with a high level of security, integrity, certified as SIL-4 under the applicable railway standards EN50126, EN50128 and EN50129.

11.2.7.2 Eurobalise System (Balise)

Balise is an electronic beacon or transponder placed between the rails of a railway as part of an automatic train protection (ATP) system. A balise which complies with the European Train Control System specification is called an Eurobalise. Eurobalise are used for sending the ETCS message to trains.

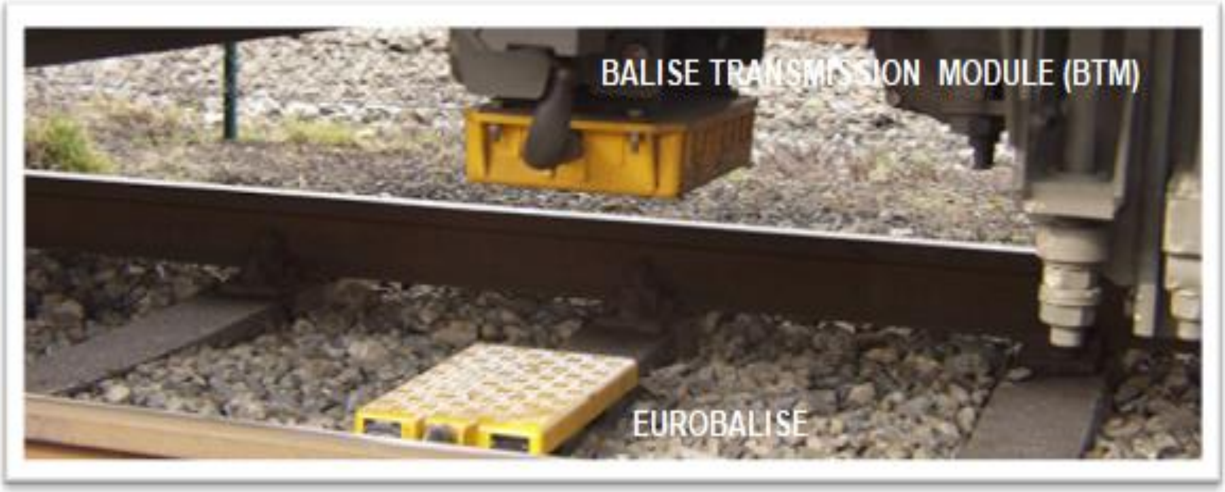


Figure 11-10: Balise/Transponder -Eurobalise

The Balises needs no external power supply as it is energized by the passing train. In response to radio frequency energy broadcast by Balise transmission Module mounted under a passing train, the balise either transmits information to the train or received information from the train (rarely used). Balise group consists of one to eight balises. Each balise is uniquely identified within Balises group and each balise group also has a unique identity. Balise group is used to help the train determine its direction of travel. The train normally determines its direction of travel from the order in which it passed over the balise group. Direction is more quickly established when a balise group consist of two or more balises. Multiple balises, within a balise group, permit the transmission of more data. This also allows for redundancy as the same message can be transmitted from more than one balise. If one balise fails to be read for whatever reason, the other balise may be read thereby ensuring delivery of telegram. Collectively, the telegrams from a balise group form an electronics message.

The Eurobalise system consists of:

- **Balise**: beacons, fixed or controlled type, situated along the railway track, which are energized and enabled to transmit only when the train antenna is above them.
- **On-board transmission system**: consisting of the antenna unit and Balise Transmission Module (BTM) function.

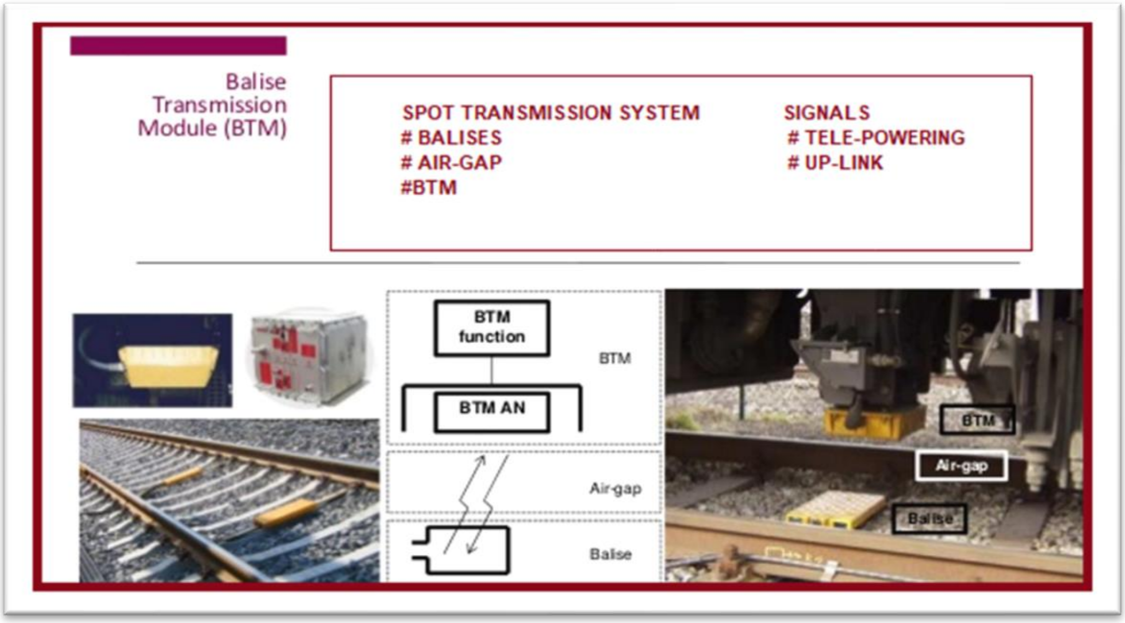


Figure 11-11: Balise Transmission Module (BTM) System

The system function of balise information transmission system is accomplished by two signal transmission processes, i.e., the tele-powering transmission process where the on-board Balise Transmission Module (BTM) radiates energy waves to activate the ground balise to start work and the up-link signal transmission process where the ground balise transmits important control information to the train subsequently.

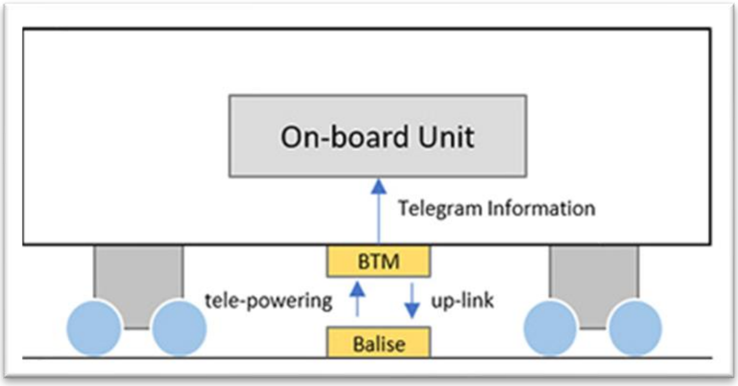


Figure 11-12 : Eurobalise interface with on-board unit

Through the two processes, the ground-train point-mode information transmission is achieved, and the telegram information, including geographical position, route data and temporary speed limit is passed to the on-board unit which continuously calculates the dynamic speed profile from these data and other information concerning train performance, thus realizing the real-time supervision of train speed.

Therefore, balise information transmission system is very important for train operation safety.

11.2.7.3 Network Transmission Gateway (NGT)

The NTG (Network Transmission Gateway) is an interface gateway between signalling equipment network and radio communication (LTE/GSM-R) subsystem network. The NTG converts the information coming from the RBC into LTE/GSM-R protocol and vice versa, allowing the communication between the RBC and with ETCS level-2 equipped trains.

11.2.7.4 Lineside Encoder Unit (LEU)

The LEU (Lineside Encoder Unit) is the safe equipment that interfaces between the Interlocking and other external system, and the switchable Eurobalises installed on the track. This equipment is able to interface with several switchable Eurobalises at the same time. It sends the suitable predefined ETCS messages, according to the information received from the Interlocking or external system. LEU is required only for some external interface with interlocking.

11.2.7.5 Marker Boards and signage

When the system is implemented as ETCS Level 2 without lineside signals, additional signage is provided in the form of ETCS block markers and shunt entry boards. A block marker can mark the start or end of a signalled move. A shunt entry board can only mark the start of a signalled move. Each block marker and shunt entry board will be provided with an identification plate.

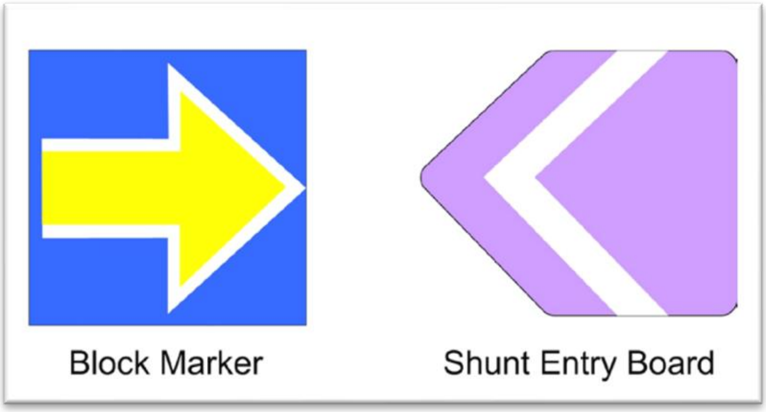


Figure 11-13: Block Marker and Shunt Entry Board

The ETCS marker board is installed along the track at each end of block section. They are used to indicate to the train driver the exact location where he needs to stop the train in the case of end of movement authority. The marker board is a coloured and reflecting panel in order to be visible from a far distance to train driver.

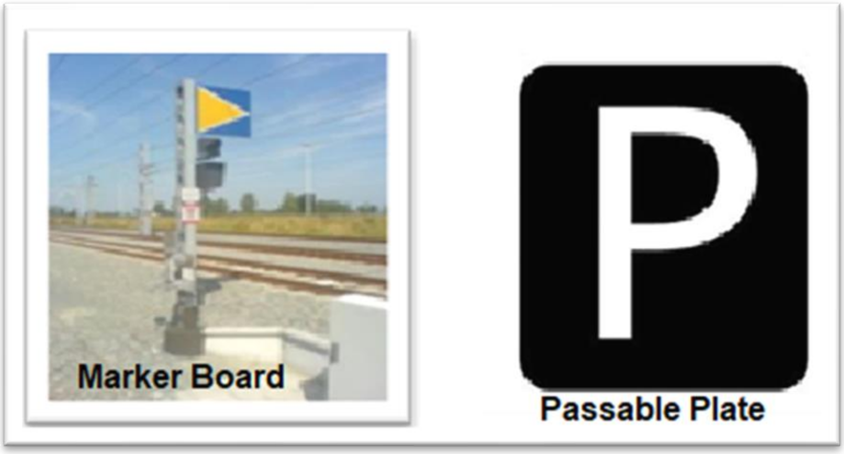


Figure 11-14: ETCS Marker Boards and Passable Plate

A block marker may be designated as ‘passable’ by a passable plate. Any block marker, without a passable plate, is non-passable. All shunt entry boards are non-passable. Additional signage is also provided at the boundary of ETCS Level 2 without lineside signals area in the form of:

- Warning of start of cab signalling boards
- Start of cab signalling boards
- End of cab signalling boards.
- Permanent Speed Restriction boards etc.

11.2.8 ETCS Level-2 On-Board/Train Borne Subsystem

The on-board subsystem placed in the train is a computerized system to supervise the train movement. The trackside ETCS system communicates with trainborne subsystem in order to allow the safe train movement. The ETCS system and main trainborne subsystem are shown in Figure 11-15 :

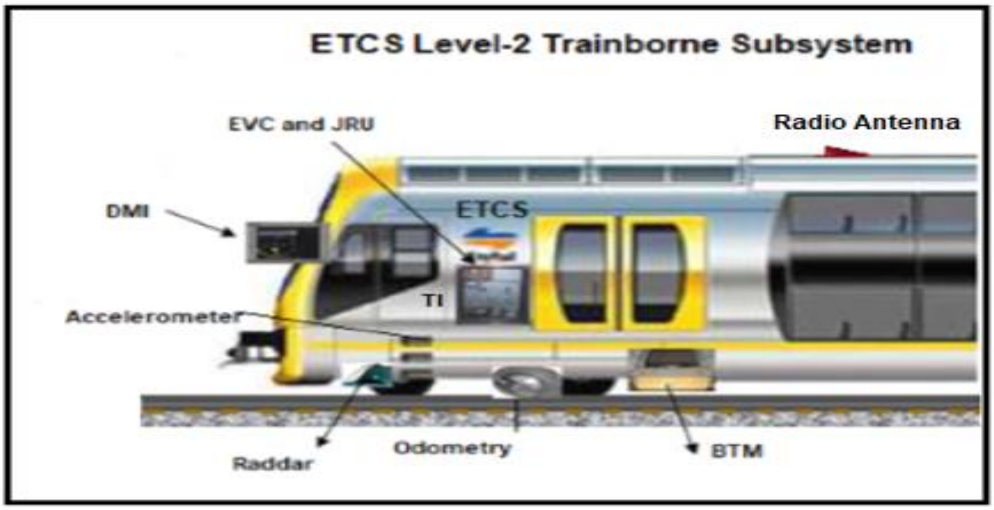


Figure 11-15: ETCS Train borne Subsystem

The trains are operated at such high speeds that wayside signals can hardly be recognized by driver eye, the on-board equipment which display cab signalling system shall be indicated a permissible train speed on the driver's console (display), which is employed along with wayside- signal system. The on-board equipment have very important functions.

The main functions of on-board equipment are as follows:

- Reception on-board from the RBC of data including movement authorities, information about the status and characteristics of the track ahead and the distance to the next balise. The train sends its position with respect to Eurobalises back to the RBC
- Calculation of the dynamic speed profile, in relation to the train characteristics which are known on-board
- Selection of the most restrictive speed value to be observed at the locations ahead
- Comparison between the train's actual speed and the permitted speed with, if necessary, mandatory brake application
- Display of indications and provision of alerts/warnings to the driver
- Provision of planning information to the driver about the route ahead enabling efficient driving.

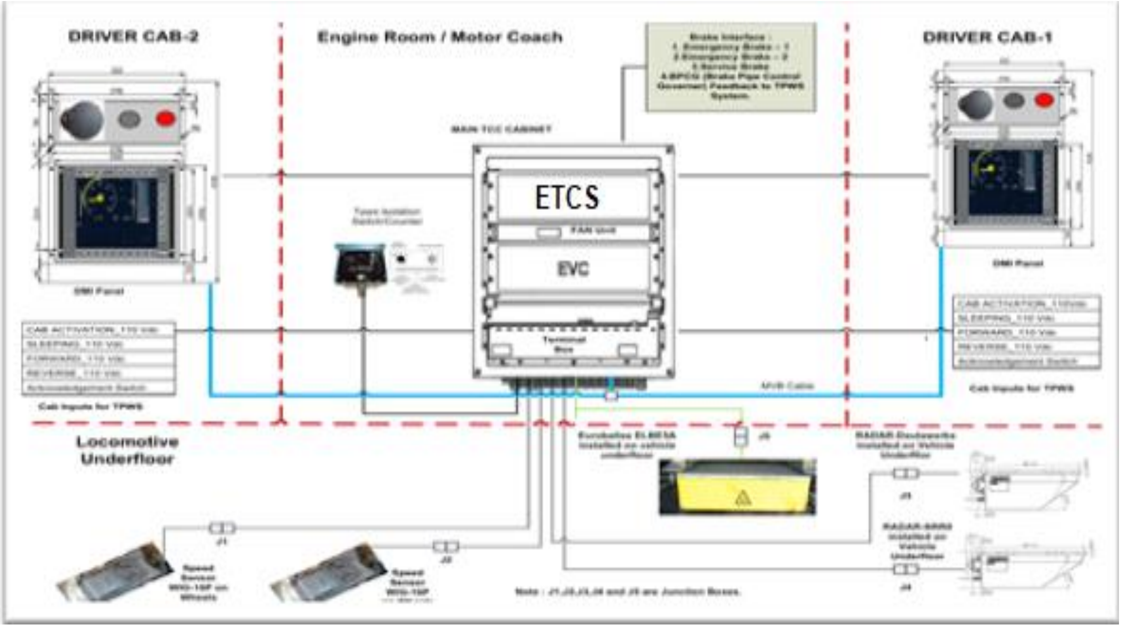


Figure 11-16: Overview of Onboard components & Interface

More details about the ETCS train borne system are described as below in details.

11.2.8.1 EVC (European Vital Computer)

EVC (European Vital Computer) is the on-board computer, which safely processes the train borne functions on the basis of the following:

- Information received from the wayside equipment
- Data introduced by the driver
- Data coming from on-board sensors
- The driver can interface with EVC trough the DMI (Driver Machine Interface)

Figure 11-17: European Vital Computer (EVC)

11.2.8.2 DMI (Driver Man Interface)

Train separation system use the term of Virtual Signals, because the concept of a traditional railways signal, like fixed light lamps, is physically moved to the train DMI (Driver Machine Interface unit). The ETCS on board equipments communicates with the driver of train via the Driver machine interface (DMI), an in-cab display. DMI is located in a prime position on the driver’s desk. The information is transmitted by wayside RBC & RBC to on-board equipment. DMI will provide the driver with all necessary ETCS information needed to determine:

- The distance that the train has permission to travel
- The maximum speed which the train should not exceed
- The point at which the driver needs to start braking to avoid intervention by ETCS on-board equipments

The other important information is also displayed on the DMI (Driver Man Interface) monitor to driver in cabin as shown below:

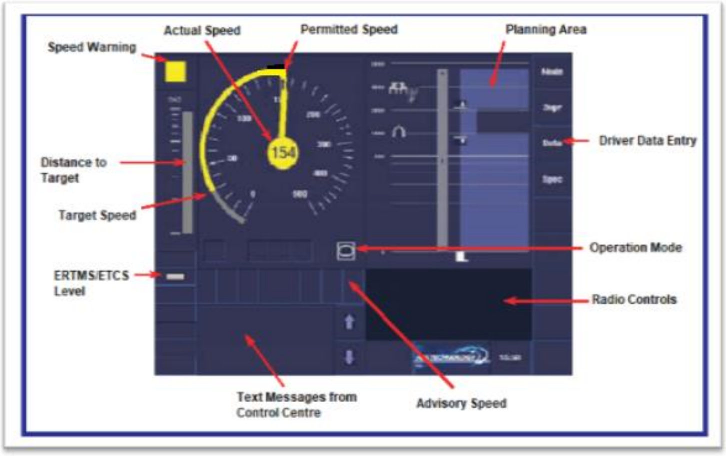


Figure 11-18: DMI-Monitoring display unit

DMI screen may be touch- sensitive and/or have buttons to permit the driver to input train information, request permission to move and acknowledge certain events. DMI has a series of button and soft key on the right-hand side. Their function changes according to the operating status. The text message sent from ETCS or by the train shall be also shown in the DMI for monitoring information. Other system information like -Radio controls, ETCS levels, Planning area, Operation mode, different levels of speed, Station location, Bridge, Tunnel, Slope and speed restriction points etc. shall be provided on DMI for driver information/action.

11.2.8.3 Odometry Subsystem

The odometer is responsible for calculating the distance run by the train, typically consisting of redundant tachometry and radar, which is able to calculate distance, speed and acceleration.

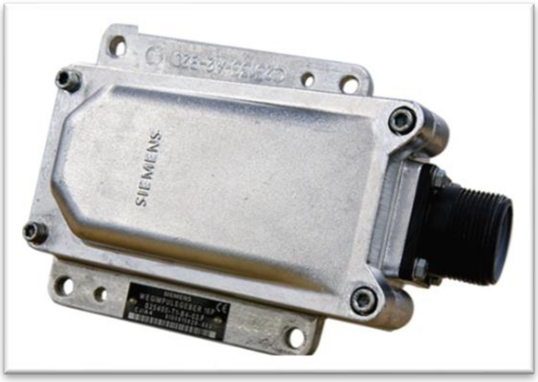


Figure 11-19: Odometry System

The Odometry is a technique for estimating the position and speed of a vehicle on wheels, based on information from sensors for the measurement of the covered distance. An odometer measures the covered distance of a vehicle by sensing the rotations of its wheels, featuring from a given size\radius.

11.2.8.4 Radar

Based on the Doppler principle, the radar sensor gives an image of the ground displacement in order to provide information about train speed and the covered distance.

Microwaves transmitted by radar are reflected by the ground. The Frequency difference between emitted and received radiation, proportional to train speed, is computed by a processing unit. The radar sensor contains embedded software and is powered by the train battery.

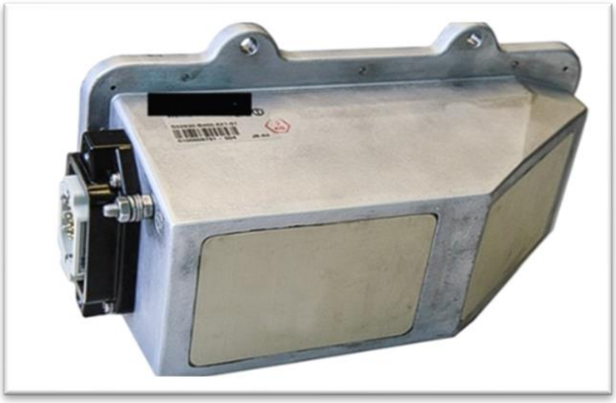

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Figure 11-20: Radar System

11.2.8.5 Train Interface (TI)

The TI is the interface that allows the ETCS to exchange information (e.g. ETCS will receive the status of the direction controller through the TI) and issue commands to the rolling stock (e.g. ETCS will send the rolling stock, the command to apply the brakes)

11.2.8.6 Juridical Recording Unit (JRU)

The Juridical Recorder Unit (JRU) provides ‘black box’ functions, i.e. it stores the most important data and variables from train journeys, allowing later analysis. The data recorded by JRU can be used for legal evaluation purposes. JRU logs and stores all information that could be used as evidence in the event of an accident also. It records the details of train movements and details of data communication (Eurobalise, Radio, ETCS), displays and driver actions.

Figure 11-21: Juridical Recording Unit (JRU)

11.2.9 Minimum Headway

The signalling headway between the trains is defined as the time between two trains passing the same location on a railway line at a defined speed profile. Whilst there is a theoretical calculation based on the inbuilt technical capability of the system, the actual headway is dependent on various location and system specific factors including, but not limited to, differing maximum speed of trains and braking capabilities of trains, gradients (affecting stopping distances), the granularity of train detection, junctions and operational stopping patterns. Therefore, some factors that affect practical capacity can be discounted. In addition, the infrastructure design for stations and junctions has been developed with sufficient platform capacity, approach tracks and grade separation to avoid conflicting movements.

The minimum signalling headway of the route will be defined by the worst-case location or condition necessary to maintain safe separation based on maximum permitted speed between trains operating at the defined operational speeds. It is taken as the time between the front nose of successive trains passing any point along the line at the defined operational speed. The practically planned maximum operational capacity is less than the sum of trains at minimum headways to allow some margin for day to day variability in operation including the promptness of train dispatch, driving style etc. This is separate from the timetabled allowance for delays which is captured in planned journey time, either at specific locations, practically before final destination or using the wider practice, adopted in most high-speed rail operation, of timetabling trains at a percentage of maximum permitted speed.

With a fixed block train detection system (assumed axle counters) the control system will detect the moment the rear wheels of a train of the maximum length passes into the following track section. Until that moment the train can be at any point within the length of the first train section and has to be assumed at the most adverse position (i.e. at the start of the section). The Train Detection (TD) system confirms the train has cleared the first section and reports this to control the system. The latter updates the Movement Authority (MA) for the following train and transmits this to it by GSM-R radio under ETCS level 2. Until this moment the following train has to proceed with the capability of stopping before the start of the now cleared first track section. There are a number of processing and transmission actions by the train control system for which time has to be allowed.

The minimum stopping distance of the following train, in addition to its technical braking capability from its actual speed including any influence of gradient, will include the reaction time of the driver or Automatic Train Operation (ATO) system to receive a command to stop the system, the reaction time of the system should the driver (or ATO system) not respond in that time and the time for the brakes to build up to full effect.

Additionally, there is a degree of uncertainty of the exact position of the train along the line. Whilst this is reset at the point of passing each European Train Control System (ETCS) balise group, during its passage between balise groups it is dependent upon on-board odometry which has a technical accuracy tolerance. The worst case for this positional tolerance is assumed as being that which could build up over the full distance between balise groups to the moment before reaching the next balise group (whereupon the positional uncertainty is eliminated). Whilst only under-estimation of distance travelled is adverse, in practice the full 4% range between maximum and minimum limits is often assumed. Even with this conservative assumption, at high speed odometry tolerance represents less than one second – and could be assumed to be zero by appropriate placement of balises at key headway locations.

With ETCS it is possible to locate the ‘End of Authority’ (EOA) in a different location to the ‘Supervised Location’ (SvL) – in signalling terms this is equivalent to a signal overlap. The EOA is defined as the location where the train is supposed to stop with the driver/ATO following the ETCS speed supervision curves – and this is generally where the block markers will be positioned (to facilitate degraded mode operations). The SvL is defined as the point in which the train is guaranteed not to pass. The distance between the EOA and SvL can be variable and used to provide additional tolerances. For the purposes of this report, an assumed EOA to SvL distance of 300m is considered (and is additional to other tolerance such as Odometer tolerance). The train would therefore take another 4.32 seconds to traverse this additional distance at 250 kmph.

11.2.9.1 Key Technical Parameters for headway calculation

A. Reference Train

- Maximum permitted speed = 250 kmph (Approx. 70m/s)
- Maximum length = 400m

- Allowance for driver reaction / response time = 6 seconds
- Response time of Automatic Train Operation (ATO) = 3 seconds
- Brake actuation time = 3 sec
- Braking retardation rate assumed for headway calculation = 7%g (0.687m/s2)
- Maximum braking retardation rate = 9%g (0.88m/s2)

B. ETCS Level 2 Control System

- Train detection (TD) system reporting time = 2 seconds
- Interlocking processing and transmission time = 5 seconds
- Movement authority (MA) transmission time = 2 seconds
- Train On-Board ETCS reaction time = 1 seconds
- Odometry error +/- 2 %
- End of Authority (EoA) to Supervised Location (SvL) = 300m

C. Limiting Infrastructure Characteristics

- Maximum permitted diverging speed at turnouts = 80 kmph (22.23 m/s)
- Standard length of track sections for train detection = 1600m
- Length of track detection section at turnout = 400m
- Turnout operational time = 9 seconds
- Turnout locking and processing time = 3 seconds
- Gradient profile max taken =1.67 (Vertical)

Table 11-4 : Summary of Operational Parameters for 200 kmph

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
Braking Distance (BD)		2250 m	40.5	Braking rate 7%g (0.687 m/s2) Value for braking to rest from 200 kmph (55.6 m/s)
Acceleration Distance (AD)				Distance required for the train to re-gain line speed Values taken from High Speed reference train performance

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
Train Protection (TP)	Overlap	300 m	5.4 (@ 200 kmph)	Difference between End of Authority and Supervised Location (EoA and SvL)
	Odometry Tolerance	+/- 2%	1	Worst case positioning
	Total		6.4	
Train System (TS)	ETCS Response	1s	1	Receipt of a MA message to interface with the train systems/Driver Machine interface
	Brake Actuation	3s	3	Time from brake command to start of retardation
	Total		4	
Driver Response (DR)		6s	6	Time from DMI display to actuation of controls (Note- for acceleration this also includes train system response of 2s)
Driver Assist. Response (DAS)		3s	3	Time from system input to interface with train systems
Train Location Section (TLS)		1600 m 400 m	28.8 s 7.2 s (@200kmph)	Length of the infrastructure-based sections used to identify train positions -open route and junctions
Train Detection (TD)		2s	2	Detect and report /Process detection at interlocking

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
Junction Operation (JO)	Interlocking Processing	3s	3	Issue instruction to move report /process detection at interlocking
	Junction Movement	9s	9	Trackside mechanical movement
	Total		12	
Issue Movement Authority (IMA)	Interlocking /RBC Processing	5s	5	Interlocking process route/ transfer to RBC. RBC evaluates and constructs MA
	RBC Transmit	2s	2	MA Processed. Transmitted and received by train
	Total		7	

Table 11-5 : Summary of Operational Parameters for 250 kmph

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
Braking Distance (BD)		3505 m	50.5	Braking rate 7%g (0.687 m/s2) Value for braking to rest from 250 kmph (70 m/s)
Acceleration Distance (AD)				Distance required for the train to re-gain line speed Values taken from High Speed reference train performance
Train Protection (TP)	Overlap	300 m	4.4 (@ 250kmph)	Difference between End of Authority and Supervised Location (EoA and SvL)
	Odometry Tolerance	+/- 2%	1	Worst case positioning

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
	Total		5.4	
Train System (TS)	ETCS Response	1s	1	Receipt of a MA message to interface with the train systems/Driver Machine interface
	Brake Actuation	3s	3	Time from brake command to start of retardation
	Total		4	
Driver Response (DR)		6s	6	Time from DMI display to actuation of controls (Note for acceleration this also includes train system response of 2s)
Driver Assist. Response (DAS)		3s	3	Time from system input to interface with train systems
Train Location Section (TLS)		1600 m 400 m	23 s 5.8 s (@250kmph)	Length of the infrastructure-based sections used to identify train positions -open route and junctions
Train Detection (TD)		2s	2	Detect and report /Process detection at interlocking
Junction Operation (JO)	Interlocking Processing	3s	3	Issue instruction to move report /process detection at interlocking
	Junction Movement	9s	9	Trackside mechanical movement
	Total		12	

Headway Element	Technical Element	Value	Headway Contribution(s)	Comment
Issue Movement Authority (IMA)	Interlocking /RBC Processing	5s	5	Interlocking process route/ transfer to RBC. RBC evaluates and constructs MA
	RBC Transmit	2s	2	MA Processed. Transmitted and received by train
	Total		7	

11.2.9.2 Calculation of Signalling Headway for open line @250 kmph:

This is the general service condition calculated for the maximum permitted speed. The gradient is treated as level given the absence generally of long continuous sections of rising or falling gradients on the route section over which 250 kmph (or 200 kmph) would be permitted. These factors are shown in the diagram below:

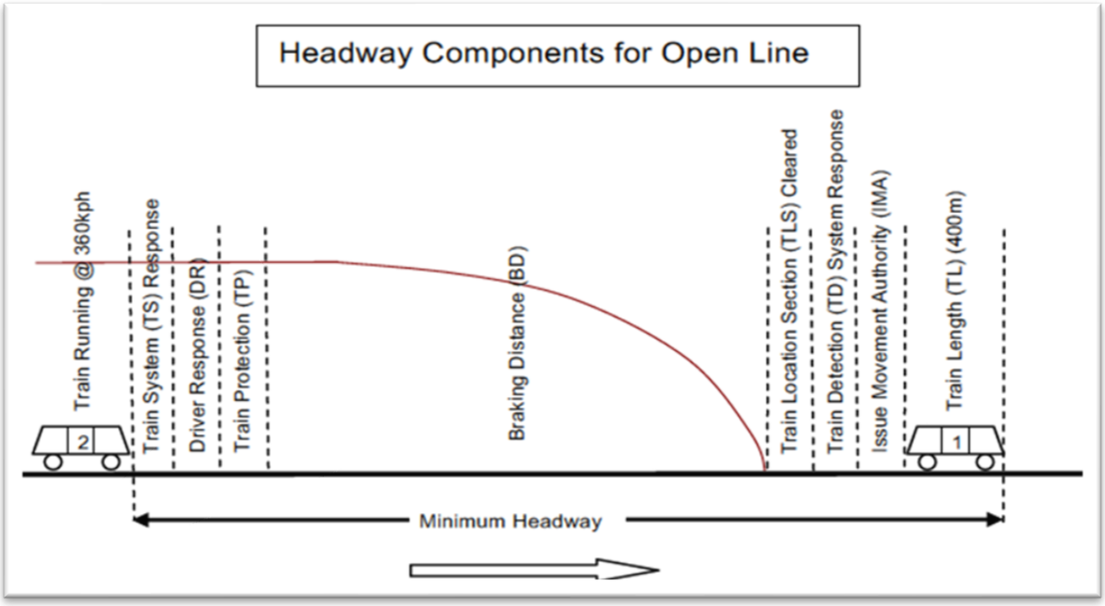

Headway Components for Open Line
Train Running @ 360kph
2
Train System (TS) Response
Driver Response (DR)
Train Protection (TP)
Braking Distance (BD)
Train Location Section (TLS) Cleared
Train Detection (TD) System Response
Issue Movement Authority (IMA)
Train Length (TL) (400m)
1
Minimum Headway

Figure 11-22: Headway Components for Open Line

Using the technical assumptions: (For 200 kmph)

- The time for the first train of maximum length to traverse a standard track section and then to clear it is 36seconds (1600m+400m) / 55.6m/s
- The braking distance of a train is defined as s=v2 /2a. Assuming a service braking rate of 7%g (0.687m/s2) this gives a service braking distance of 2250

meters. A train travelling at 55.6 m/s will take 40.5 seconds to traverse this distance.

- Therefore, signalling headway is (36 + 6.4 + 4 +6+2+ 7+40.5) = 102 seconds
- The maximum number of signalling paths per hour is then 3600 / 102 = 35.3
- The maximum operational capacity is 35.3 x 0.75 = 26.47 (26) paths per hour.

Using the technical assumptions: (For 250 kmph)

- The time for the first train of maximum length to traverse a standard track section and then to clear it is 28.8 seconds (1600m+400m) / 69.4m/s
- The braking distance of a train is defined as s=v2 /2a. Assuming a service braking rate of 7%g (0.687m/s2) this gives a service braking distance of 3505 meters. A train travelling at 69.4m/s will take 50.5 seconds to traverse this distance.
- Therefore, signalling headway is (28.8 + 5.4 + 4 +6+2+ 7+50.5) = 103 seconds
- The maximum number of signalling paths per hour is then 3600 / 103 = 35
- The maximum operational capacity is 35 x 0.75 = 26.25 (26) paths per hour.
- The maximum capacity in trains per hour (tph) is taken as no more than 75% of the number of train paths per hour at the worst-case signalling headway in line with recommendations from the UIC (International Union of Railways). The maximum operational capacity is 35 x 0.75 = 26 paths per hour.

The minimum headway (design for open line @ 250 kmph) that the signalling system can support is 2.5 to 3 minutes. The actual operational headway is dependent on various location and system specific factors including, but not limited to, differing maximum speed of trains and braking capabilities of trains, gradients (affecting stopping distances), the granularity of train detection, junctions and operational stopping patterns. The actual operational headway for SilverLine rail transit in Kerala (Thiruvananthapuram to Kasaragod) may be 10-15 minutes.

11.2.10 Interlocking System (IXL)

Interlocking is not an ETCS component, but it plays an important role in the signalling system. Interlocking guarantees safety for train movements or routes and ensures that the route for a specific train is maintained and that incompatible routes are not simultaneously established. The Interface between the interlocking and ETCS trackside subsystem is necessary in almost all ETCS structures. ETCS-RBC has the static information about the railway track layout and track elements. The dynamic information for calculating the movement authority is needed from the interlocking system. This means that either the route information or statuses of trackside elements is required from the interlocking system.

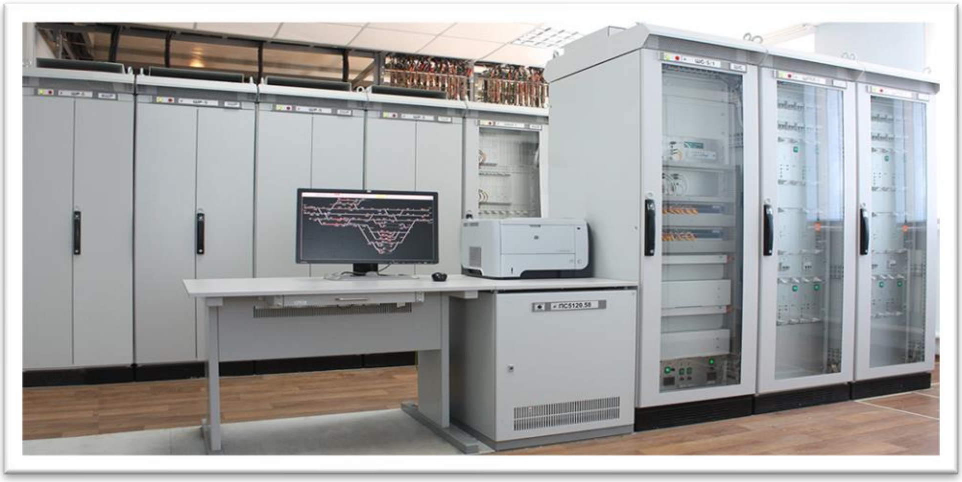


Figure 11-23: Computer Base Interlocking System (Indoor system)

The control system that deals with the line management and thus the routing of trains is called interlocking. The interlocking system processes the information concerning with the trackside signalling system in order to set the safe route for the train and interfaces with the centralized traffic control and the RBC. The main functions of the interlocking are:

- Route setting
- Conflicting routes prohibit
- Approach Locking
- Route Locking
- Turnout Locking
- Proceed Indication

In addition to the route being established and locked, for a proceed indication to be given to the train driver the following conditions are required to be proved:

- All turnouts in the line of route shall be set, locked and detected in the position required
- All track circuits and axle counter sections in the line of route shall be clear for Main Routes
- Specified track circuits in the line of route shall be clear or occupied for a period of time for Call-on and Shunt Routes
- All Stopping Point indications which allow conflicting moves shall be proved to be at stop
- Route Locking and Approach Locking shall be proved to be effective.

This system is used for controlling train movements into or out of stations automatically from a workstation (computer system). All the stations having points, track detection and crossing (Points) will be provided with workstations for local control. The station and yard layout will be clearly indicated on workstation (VDU) with position of points, track detection system etc. The setting of the route and clearing of the signals will be done by a workstation, which can be either locally station operated or operated remotely from the Operation Control Center (OCC). The local control can be achieved by the local control system (workstation) at each station. The local control system at each station controls the point machine, crossover and adjacent intermediate crossover.

A station consists of a number of parallel rails greater than two and their switches, which gives the possibility to route trains on different tracks. The path of a train leaving a station from the beginning is called route. If the train had to follow only a single track between an origin and a destination, an ATP/ATC system like the one just presented would be roughly adequate. Indeed, home and destination of a rolling stock is typically a station and there is more than a path (Path 1, Path 2) to go from an initial point A, to a final point B shown in below figure as:

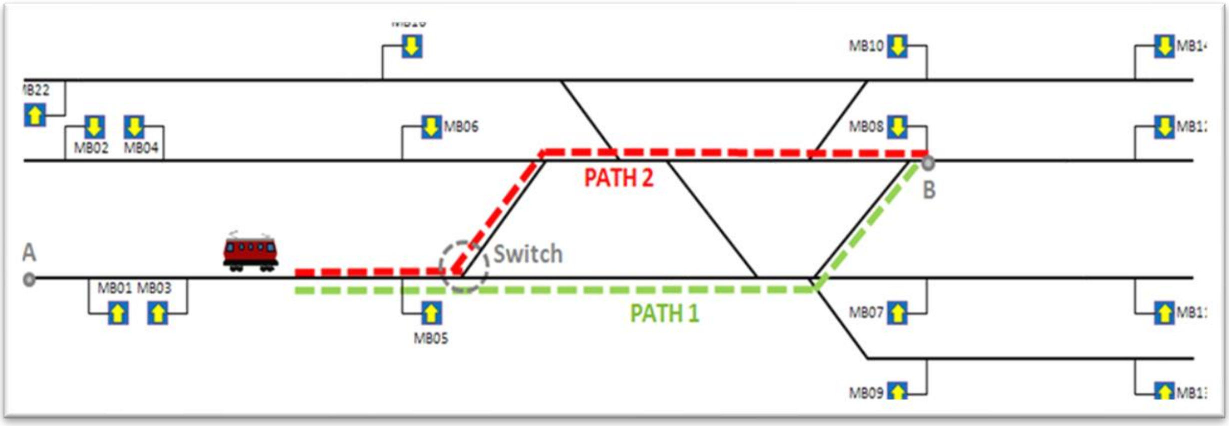


Figure 11-24 : Two possible routes from A to B

The Interlocking facilitates external & internal interface with trackside signalling equipment, surveillance equipment, RBC, GSM-R/LTE etc. and the CTC equipment's. The interlocking system should have hot standby, self- diagnostic and event logging function (in built datalogger). The main equipments of the interlocking system shall be a redundant configuration with high reliability. The interlocking system modules shall be hot-swapped and auto configured. The optical fiber network shall be used for transmission of data. The transmission network shall be configured with redundant architecture for high reliability.

The wayside signals shall only be located at interlocking (where crossovers, diversions are present). The wayside signals shall only indicate the status of routes at their entrances. These wayside signals shall not be the primary indication of route status. The primary indication shall be the train operator/ driver's display in the cab.

The interlocking will be compatible with ETCS level-2 and Central Control Center application. The interlocking system will conform to the latest international standard and fulfilling EN-50159 requirements for communications.

11.2.11 Electric Point Machine

Point Machine is an important factor in the safety of rail service. They need to operate with precision to be reliable and withstand high loads. Point machine required for a high-speed rail line shall be high power and reliable, that is, to provide connected rail with strong force, to endure strong vibration and have a robust lock function. The electromechanical point machine provides the electrical drive of the switch, its locking and detection in end positions, which is highly recommended for High Speed rail line. In addition to the internal locking and to ensure safety, the point machine is equipped with an internal “anti-veering “device to counter the vibration effect caused by passing rolling stock. The point machine can be easily adapted to any network or interlocking.

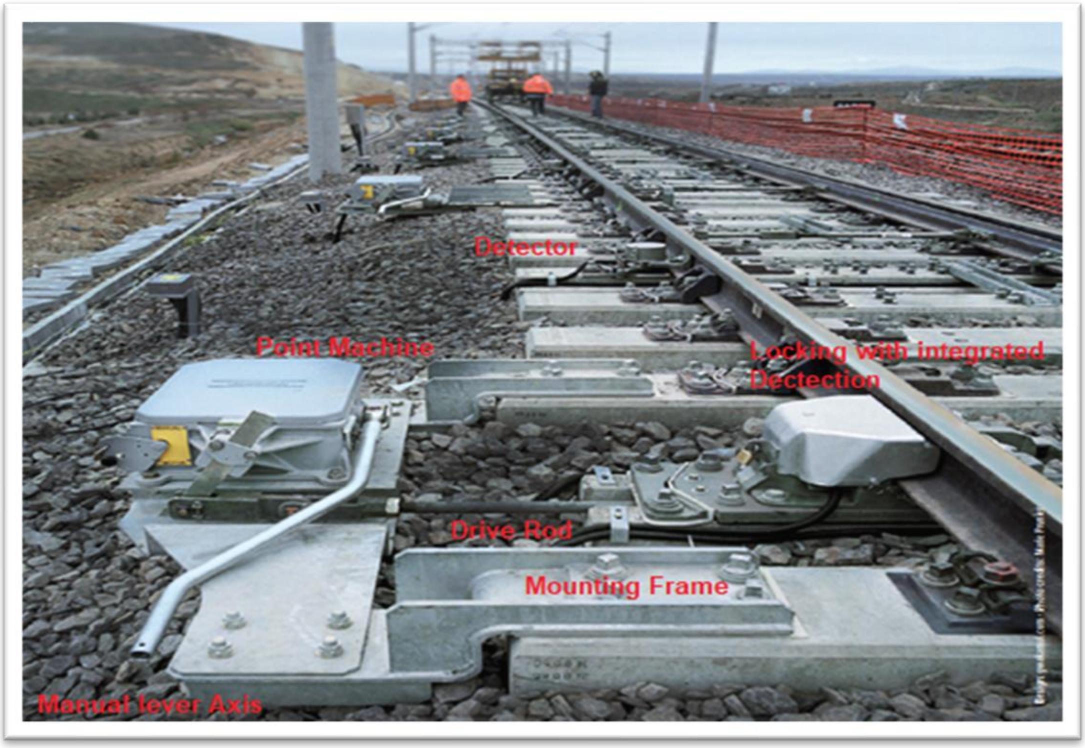


Figure 11-25: Point Machine at Main Line

Point Machine shall interface with interlocking system. It shall have performed independently the monitoring & control the point and crossing. Point machine shall be of electrical type, operating on either 380-415 V 3 Phase AC or 110 V DC. Point machine provided on Main -Line shall be Non- Trailable and those provided in Depot shall be preferably of Trailable type. Points machine shall be proven to have high durability in a wide range of application and climatic conditions.

11.2.12 Track Vacancy Detector

Track detection system shall be used for the purpose of detecting the presence on tracks. Train detection systems shall operate reliably for all vehicle types (including maintenance vehicles) and for all modes of vehicle operation. The arrangements shall ensure that there is no loss of train detection during the passage of all types of rail vehicles including the shortest vehicles, vehicles with the longest wheelbases, and light vehicles (including rail mounted maintenance vehicles).

Each block section occupation status (occupied or clear) must be transmitted to the IXL system. Two types of train detection system exist: track-circuit and axle counter that still remain in place to supervise the train location and the train integrity.

In a high-speed rail system in the world, Axle Counter and AFTC are used widely. Both systems are proven and safest train detection device for high speed rail systems. The axle counter is cost effective system so that it is widely used both in Europe and outside.

An axle counter is a device on a railway that detects the passing of a train between two points on a track. A counting head (or detection point) is installed at each end of the section, and as each train axle passes the counting head at the start of the section, a counter increments. A detection point comprises of two independent sensors: therefore,

The device can detect the direction and speed of a train by the order and the time in which the sensors are passed. As the train passes a similar counting head at the end of the section, the counter compares count at the end of the section with that recorded at the beginning. If the two counts are the same, the section is presumed to be clear for a second train.

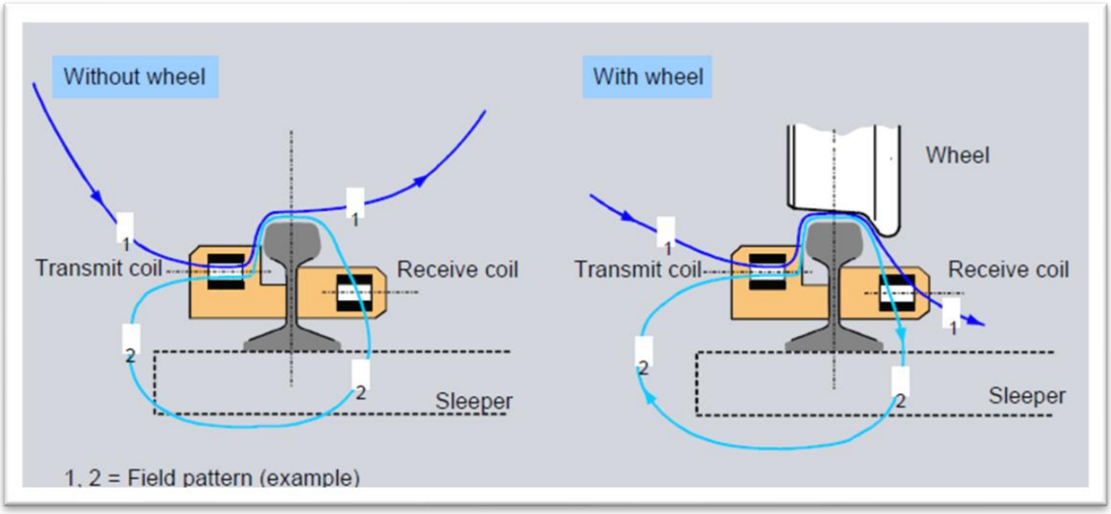


Figure 11-26: Axle counter Field Pattern

This is carried out by safety critical computers called ‘evaluators’ which are centrally located, with the detection points located at the required sites in the field. The detection points are either connected to the evaluator via dedicated copper cable or via a telecommunications transmission system. This allows the detection points to be located at significant distances from the evaluator. This is useful when using centralized interlocking at equipment, but less so when signalling equipment is distributed at the lineside in equipment cabinets.

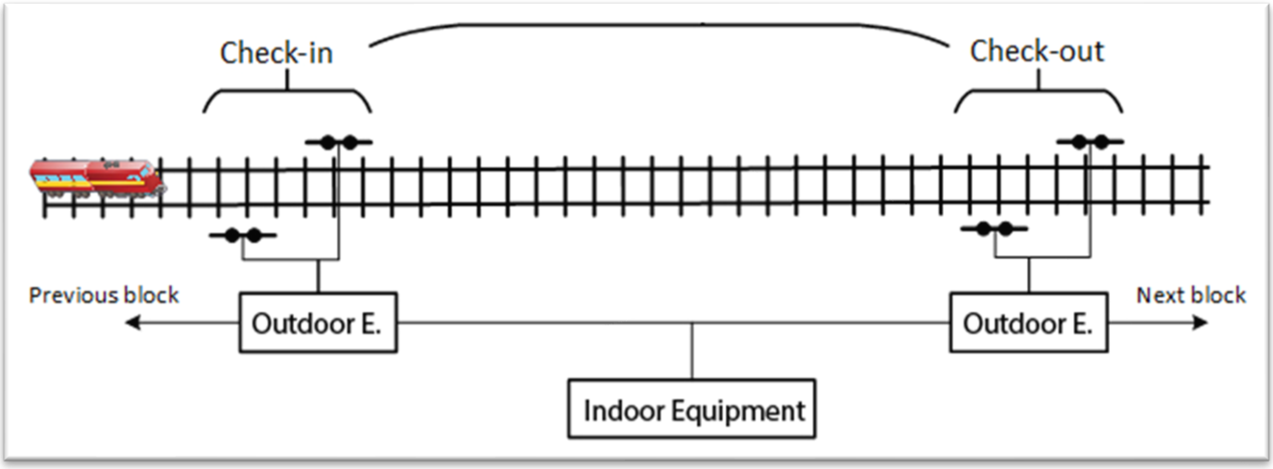


Figure 11-27: Axle counter track layout

The main components of the Axle counter system are:

- Outdoor equipment (detection points in the track area)
- Information transmission equipment (cables)
- Indoor equipment (evaluation, indication & resetting)

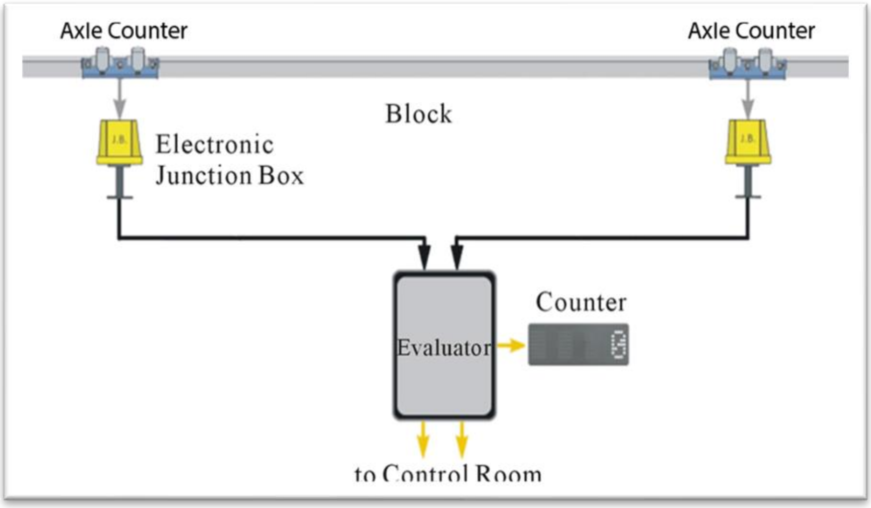


Figure 11-28: Axle counter Components

Axle counter applications: Axle counters have been finding more and more uses on modern safety signalling systems in railways. These are being used presently for the following:

- Monitoring of berthing tracks in station areas and yards.
- Monitoring of point zones in station areas and yard.
- Automatic Signalling systems.
- Block working through axle counters using multiplexers (USBI) with cable, OFC or radio communication (Last Vehicle Checking Device /Axle Counter Block Working/Block Proving by Axle Counter).
- Level-crossing warning system using axle counters.
- Intermediate Block Signalling in Double line sections.

Axle counter advantages:

- It is not affected by weather condition.
- It does not get affected either by the flooding of track or poor maintenance of tracks, unlike the track circuit, which is highly susceptible to these conditions.
- It achieves train detection at high speed of 350 kmph.
- An axle counter system can cover a very long section up to 15 km.
- It does not get affected either by flooding of the track or poor maintenance of tracks.
- It does not require insulating rail joints; thus, rails can be continuously welded. This reduces track maintenance cost, low wear and tear of tracks and vehicles and in addition to increased travelling comfort.
- Efficiency and safe working of axle counters does not depend on various track parameters and climate condition such as length, ballast condition, drainage, stray voltage and currents, track feed voltage and lead cables, etc. like track circuits.

Axle counter is not affected by weather conditions and achieves reliable train detection at high speed of 350 kmph. In view of the above advantages, Axle counters have been used in vital train detection schemes on a large scale for high speed in Europe and outside of Europe. As per the weather condition & hilly terrain of Kerala, Axle counter is recommended for track detection system for Silver-Line project.

11.2.13 Automatic Train Supervision (ATS)

ATS (Automatic Train Supervision) is the computer system that totally manages, and controls train operation and train route based on the schedule during train traffic control. This equipment is indispensable for achieving high-density operation. It is a versatile system that can also accommodate a large-scale route inspite of a simple configuration.

The ATS (Automatic Train Supervision) subsystem is devoted to supervising the railway traffic circulation and to perform the diagnostics of the equipment of the system. It supports the complete Traffic Management life cycle, with functions to plan, regulate and optimize the train traffic circulation, to manage the infrastructure state, to monitor and to perform diagnostic of all involved equipment.

Figure 11-29: ATS system at Control Centre

Main functions of ATS:

- Train schedule supervision: Practicable train schedule is generated from fundamental train schedule and supervised based on the actual train operation in ATS. Fundamental train schedule is planned by the traffic dispatcher supported by the train schedule planning system. ATS prepares the train departure order for route setting. In case the train schedule is changed based on operation regulation, the train schedule will be adjusted.
- Train tracking: All trains are always track based on the train detection data and the train number receiving data and indicates the train location and train number on the terminal display and mimic panel geographically.
- Route Setting: Route setting function has three setting modes. One is the automatic route setting mode based on the practicable train schedule, one is the manual route setting from ATS system, and other is the manual route setting mode for the ARS (Automatic Route Setting).
- Operation adjusting: When the train operation is disturbed because of accident, ATS shall support the traffic dispatcher and automatically adjust the operation.

ATS's system automatically makes optimum train schedule changes for operation adjustment to the traffic dispatches and provides all functions required for the entry, stepping, cancellation and changing of the train schedule. All those functions share a single integrated Human Machine Interface for displaying real-time status of the railway line, managed by a human supervision.

11.2.14 Operation Control Centre (OCC)

The Operation Control Centre (OCC) is the main brain of any high-speed rail corridor, which support safety and sustainable train operation in high speed rail. The OCC System will help in real time monitoring and better management of trains. The OCC play big role in management of train operation and supervision of all other facilities like CTC system, Signalling & Communication, Power supply, SCADA system, Traction system, Track system, Rolling stock and other safety system etc.

Figure 11-30: Example of Operation Control Centre (OCC)

Centralized Traffic Control (CTC) located in Operation Control Centre (OCC) for managing real time traffic, Safety of train movement, Rolling Stock, On board staffing and maintenance work. CTC's system interfaces to the Signalling & Communication system, ETCS-RBC & MSC, Surveillance system, Safety system, SCADA and other systems to monitor & control the traffic and to ensure the safe operations of trains online. CTC system is to construct the route of the trains from the origin upto the destination automatically and to supply all the information required for the CTC operator in order to check the normal operations of the train. In addition, under its abnormal condition, the CTC's system will provide effective alternatives to minimize the delay of the train.

The Operational Room at Control Centre (OCC), monitor the train operations of the high speed and control the operations of the train so that the trains can operate safely. All controlling centre staff should be together in the same floor and a room without bulkhead to share information, because an immediate determination is essential in case of incidents. The function of operating room will be supported by the large display panel and workstations for all the operators. The display in OCC room shows the entire track line in real-time to monitor it any time. The OCC should have the following minimum system requirements:

- Operation & Control management System
- Supervise train traffic online System
- Assignment /Instruction and information to train driver
- Maintenance management of system at Station, Depot and Line
- System surveillance for monitoring of critical systems
- Passenger facilities and information systems
- Safety and Security management system
- Notification for stations and staff of O&M
- Prevention system for Natural hazard like earthquakes, heavy rainfall, strong wind etc.
- Trouble shooting in case of emergency and accident.

The high-speed train Operation Control Centre (OCC) is normally located at one of the terminal station or central station in depot near to the line. The Operation Control Centre (OCC) is composed of several rooms that have a specific system function. The systems servers are installed in OCC. The main equipment of OCC system shall be a redundant configuration with high reliability. The OCC system modules shall be hot-swapped and auto configured. The following rooms are directly concerned by signalling system:

- Centralized Control Room
- Centralized (S&T) Equipment Room
- Maintenance Room
- Power Supply Room

The uninterrupted power supply (UPS) is necessary for signalling & communication and operation control rooms. All the centralized servers and hardware shall be connected with UPS. The power supply arrangement is designed in order to provide uninterrupted power supply (UPS) in case of general power supply breakdown.

In case of failure of main OCC due to any problem/emergency, such as earthquake, heavy fire, building collapse, power failure etc., the Backup Control Centre (BCC) equipment immediately start up to support the systems. The BCC shall be similar to main OCC with full redundancy of all Systems. The BCC will also available for training, testing, replay without disturbing the live traffic online. The Main OCC and Backup (BCC) shall be provided for this new rail corridor in order to avoid risk. The OCC & BCC shall be provided at different locations.

11.2.15 Fall -Back Block System

ETCS level-2 has high reliability, safety, punctuality and availability. The normal ATC operation shall not depend on the use of wayside signals. The ATP subsystem design shall provide some visual signals and signs at the wayside for fall-back operation. Such signals are not in practical use when operating at high speed (greater than 160 kmph). However, they shall be usable in degraded operating modes when the on-board ATC system that generates cab displays of movement authorities is not available. ATC's system failures can be divided essentially into two key events impacts:

- Single train can be affected for a significant distance and time by the failure of the ON board ATC equipment.
- Several trains can be affected over a limited distance and time by a failure of wayside ATC equipment.

But in case equipment of ETCS Level-2 fails and becomes unavailable, the Fallback Block system can temporarily work to maintain safety and smooth operation with the help of line side signals provided at each interlocking. When the Fall-Back Block system is operated, it is necessary to check no other trains exit in the protection area to keep safety operation at first. To detect trains between stations, axle counter device will be used in Fall-Back Block mode. The axle counter system has function to count number of trains, to transmit data to interlocking system. The high-speed train ATC design presently plans wayside signals at the following locations at the entrance to interlocking routes (Home signals, Diversions) in the station yard. The prime use for mainline signals is to support safe train operation when the primary on-board or wayside ATC's subsystems is not available and movement authorities cannot be received and enforced by the on-board ATC system.

At high speeds, signals shall not be visible in a useful way to the Train operator (Driver), so the train operator (Driver) must follow the cab signal indications or operate the train in ATO mode. During failures of the primary on-board or the wayside ATC system, the maximum train speed shall be limited to safe train speed as per safety manuals. The analysis shall consider maximum speeds allowable, signal sighting distance and the need to enforce the signals or not. If wayside signals shall not be enforced, the sighting distance for each signal shall be critical. In that case, high signals may be required, especially on grades and covers. Approach signals of interlocking may also be required.

If the fall-back system is complex and equipment-intense, this shall reduce overall reliability due to the increase in hardware. This could also reduce the availability as fall-back system equipment failures can impact the availability of the prime ATC system under certain circumstances. The ETCS/ATC system procurement shall specify high availability normal operating mode so that High Speed Train (HST) can provide dependable, on-time service. Considering the excellent availability, of HST service worldwide, high speed train should rarely experience degraded mode operation.

11.2.16 Power Supply requirement for Signalling & Communication System

The power supply has a vital role to play in the functioning of railway signalling & communication system. There are a number of computerized/ Electronics equipment, which are associated with signals & communication, and failure of power supply may lead to failures of these equipment which may cause heavy delays to traffic. Signalling & communication system consists of a variety of equipments and gears which require different types of power supply for their functioning. The design of a Power supply system depends upon various factors such as type of installation, number of signalling & communication gears, associated power equipment and load requirement etc.

The power for signalling & communication system will be supplied from each station and intermediate equipment room (Line/Track Side). Power from overhead equipment will also be used as an auxiliary power. Regular power will be redundant loop configuration. On power receiving point, isolation transformer will be installed in each receiving power point.

The Uninterrupted Power Supply (UPS) is necessary for the signalling & communication system. The function of UPS system is to provide a stable and reliable AC and DC power supply to the signalling & communication system installations against all AC mains variations or even interruptions. This is very essential for proper movement of trains. The following functions shall be required in the UPS system:

- Back-up of the AC supply by means of uninterrupted power supplies and associated batteries
- Capacity of batteries based on system consumption and autonomy requirements (in hours)
- Provision of continuous battery health monitoring with indication and alarms on Status Monitoring panel with local control / Station Master.
- Redundancy of mains feeder (delivery from multiple cables/sources)
- Architecture and dimension of the system allowing failures and/or maintenance without service disruption (possibility to switch off one or several converters or other modules without impact).
- Modular in design with modules working in n+1 hot standby mode to provide redundancy and future expansion at any time by adding more modules.
- Provision of Lightning and Surge protection at input supply is inbuilt.
- Standard configurations adopted for small and medium size stations to increase reliability, availability and maintainability.

- Reduce maintenance efforts due to centralized maintenance and remote monitoring.
- Higher reliability due to inbuilt redundancy and integrated factory wiring.

Status Monitoring panel for local control (at Station) shall be provided. The panel consists of status indications and critical alarms of UPS to be provided in local station control room. The monitoring panel shall be of wall mounting type. Indications and alarms are provided on the panel to enable the local controller as well as the central controller to prompt signalling maintenance staff as and when there is a fault condition and help him to attend fault.

The power supply for track side equipment of signalling & communications system shall be required at every 7-8 km (Approx.) on the track side. Such equipment shall be radio system, Axle counter, Interlocking equipment, communication equipment, safety systems and power supply etc. The power supply equipment shall be provided with redundancy of main equipment.

11.2.17 Interface with Safety System

High-tech safety systems have long been an area of interest for railway network. For complete condition monitoring of trains and railway tracks as well as derived preventive maintenance tasks not only affect operating costs, But also relevant for safe train control and traffic management on the whole. Due to this maximum importance of such applications and based on the high number of components that need to be monitored on tracks and trains, a vast number of technologies and systems are available today to meet all related requirements. This plurality as well as the fact that several units might be needed for various tasks contribute to raising efforts. The safety equipment shall be installed for monitoring the condition of the track side system and rolling stock subsystems. The signals from these safety systems will be provided to train control system to ensure appropriate action to avoid an unsafe situation. Some surveillance equipment have direct effect on train operation. The surveillance system for monitoring of the following items for system safety and maintenance staff safety are as below:

The safety/surveillance equipment should be installed online side, suitable for local environment and installation criteria of high-speed rail line. The High speed train shall use an array of hazard detectors. The Signalling & Communication system communicate the data from field unit of hazard detector directly by OFC network to Control Centre (OCC). The hazard detector types may include:

- Track monitoring system
- Broken Rail detection system
- Earthquake detection system

- Rainfall & Flood detection system
- Wind detection system
- Protection staff crossing equipment
- Rail Temperature detection system
- Intrusion at trackside and in tunnels
- Fallen road vehicle Detection System
- Landslide detection System
- Dragging equipment detection System
- Fallen tree on track etc.

As new technologies are implemented in railway tunnels to make them smarter, sensors and probes retrieve parameters such as pollution, noise, human presence. These wireless devices can communicate on the Internet of Things (IoT) networks.

Each type of detection shall be evaluated for the level of risk each hazard can pose to high speed train operation, the interface to the ATC system and the required ATC system response. ATC system responses can include:

- Automatic change over from ATO mode to Manual-ATP mode. (Note that if the ATO function uses a “hands off” approach, this shall apply the service brakes until the Engineer takes the controller).
- Stop the train immediately with a service break.
- Stop the train immediately with an emergency brake.
- Block an affected section of track and the on-board ATC equipment for each nearby train determines the level of brake needed to avoid entering the blocked track or to stop the train if it is already entering or in the affected track section.

For track intrusions at stations, the choice is between automatic sensors of intruding passengers vs. customer/staff operated alarms.

- If a hazard detector is connected directly to the ATC system and a train response is forced, the hazard detector comes under National High-Speed Regulation.
- If the detector is interfaced to the ATS to generate and alarm at OCC, it is not directly connected to ATC.

Disaster Warning System (DWS) and Wayside Warning System provided for detection and warning of dangerous environmental, rolling stock conditions, natural disasters (earthquakes, floods, heavy rain, high wind, etc.), man-made incidents such as road vehicles intruding on the railway line, as well as dragging equipment detection. The signals from these systems will be provided to central equipment via interlocking system or directly by OFC network to Control Center (OCC). Some warning systems are advisory, and some interface directly with the Signalling System to stop or slow down trains.

11.2.18 Tunnel Safety System

Railway tunnels are one of the most dangerous confined spaces that thousands of people pass through every day. In case of accidents, the probability of human disaster is extremely high in addition of the crash, fire or smoke can kill.

A general set of safety measures can be defined based on these recommendations consisting of a combination of infrastructure, operations and rolling stock measures and containing preventive measures as well as measures to mitigate the impact and to facilitate the escape and rescue. Railways have always focused their efforts on the prevention of accidents. Most of the accidents preventing measures are not specific to the tunnel but have a safety impact on the railway system. The following points are required for tunnel safety as:

- In tunnel and at the approach to tunnel entrances, the installation of switches or other track discontinuities should be avoided.
- Systematic monitoring of track conditions in tunnels, track geometry, height of track, track material and track stability.
- Emergency telephone system should be provided for passenger use in tunnels, and can use them in an emergency, connected with Operations Centre (independent of train radio or mobile phone). Emergency telephone shall permit adequate and reliable communication during any emergency in the tunnel.
- During maintenance and services operations, tunnel operators need an efficient private communication network to work quickly and safely to reduce traffic interruption.
- Prevent unauthorized access to the tunnel portals or exits by signs, fencing secure locks, CCTV or local surveillance.
- Installation of fire, smoke and gas detectors in tunnel. All the Materials and equipment should be fire resistant or low smoke emission and flammability characteristics.
- Ventilation/Smoke extraction system should be provided in tunnel to draw out smoke or to create a defined air stream in order to obtain a smoke free side for rescue.
- The track drainage system should be provided to remove water from tunnel.
- Provision of walkway in tunnel to facilitate escape (normally beside tunnel wall, also in or between tracks if there is not enough space) and Handrails along the tunnel wall should be provided. The escape route and directions are marked by pictograms.
- Lighting along tunnel walls should be provided for lighting the escape routes in the event of train evacuation.
- Disconnection of the overhead line into segments in very long tunnel. Earthing device including voltage measuring instruments should be positioned at entrance.

- Tunnel alarm System: Tunnel supporting systems play a significant role in ensuring the safety of passengers, personnel, and emergency responders inside a tunnel in case an incident occurs. Tunnel alarm activates the alarming device installed in the tunnel on the basis of approaching train information received from interlocking system. On reception of alarm/warning, the railway maintenance staff working inside the tunnel shall be evacuated to the safety area.
- Prevention of fire on rolling stock: Fire protects measures such as construction measures and vehicle design to prevent the outbreak and spread of fire and use of materials which do not produce toxic substance or a large amount of smoke in the event of fire are recommended.

Operation measures such as regulations for mixed operation or regulations for carriage of dangerous goods, when optimizing operation conditions, timetables should be designed to avoid freight trains (especially dangerous goods trains) crossing with oncoming passenger trains in the tunnel as far as reasonably practicable.

11.2.19 Space Requirement for Equipment:

The field equipment of Signalling & Communication system like – Interlocking system, Radio Tower System, Surveillance System, Safety system, Networking equipment, Axle counter System, OFC System & Power supply system etc. shall be installed in the space provided adjacent to track. The space at every about 7- 8 km (Approx.) on track side shall be provided for placement of field equipment. The signalling & communication system has electronic/computerized components, shall be equipped with suitable air-conditioning in order to maintain an appropriate temperature and humidity conditions for the signalling & communication equipment. All the signalling & communications equipment room at stations, depot and line side shall be provided with the following minimum facilities:

- Air-conditioning system
- Fire protection system (as per system required)
- Earthing and Lightning protection system
- Access control (security) system.

The space required for Signalling & Communication rooms at stations, depot and Line side are as:

Table 11-6: Space requirement for Signalling & Communication System

S. No	Name of Room	Minimum Surface required	Remarks
1	Signalling & Communication equipment Room	80 Sq. Mtrs	At every station & depot
		40 Sq. Mtrs	Approx. every 7-8 km on track side
2	Station/Depot Control Room	80 Sq. Mtrs	At every station & depot
3	Power Supply System (UPS)	60 Sq. Mtrs	At every station
		30 Sq. Mtrs	Approx. every 7-8 km along the track side
4	Radio Tower	16 Sq. Mtrs	Approx. every 3-4 km along the track side
5.	Security Room (CCTV)	60 Sq. Mtrs	At every station & depot

The space for OCC & BCC, the area required shall be as per the final system configuration of the equipment and networking configuration keeping space for further expansion.

11.2.20 Cable Laying Arrangement (Trench/Duct/Tray) for Signalling & Communication System

Signalling & Communication equipment installed in track side signalling & communication room will connect with the wayside equipment via cable along both sides of the track. The cable shall be laid in trench/duct/on ladder as per location of track laid in Ground/ Tunnel/ Viaduct. The basic requirement for cable laying are:

Table 11-7: Requirement for cable arrangement

S. No	Track Position	Type arrangement	Remarks
1	Level Ground / Embankment	Trench	Size 1000-1200 mm depth x 300 mm width
2	On Viaduct	Cable Duct /Tray	Size 300-500 mm (width)
3	In Tunnel/Cut & Cover	Wall Hunger/ ladder/ tray	Size 300-500 mm (width)

Note: The arrangement for the cable laying shall be provided both side along the track.

The cable is laid in solid & rocky soil, on bridges, in culverts, in tunnel, road crossing etc. with special precautions in approved manner. The cable is laid in concrete/GI/CI/ PVC/DWC-HDPE pipes or suitable ducts or in any other approved manner while crossing the track. Cable laid across the track must be 1.2 meter (minimum) below the rail flanges. Cable markers wherever provided shall be placed at 30-40-meter interval and at diversion points. All the indoor / tunnel cable shall be fire retardant and low smoke zero halogen compliant with international standard.

11.2.21 Maintenance System

The remote Maintenance Diagnosis System (MDS) shall be provided at OCC to allow the monitoring of essential wayside and subsystems equipment. Maintenance Diagnosis System is used to monitor signalling and communication subsystems & equipment. This system triggers alerts and alarms based on the monitored component health status. This system allows to monitor the system health status and to organize the corrective maintenance as well as pre-corrective maintenance (before the failure occurs). It allows increasing the system availability and thus the reduction of the life cycle cost. This system is deployed in the OCC as well as in the Central Maintenance Control Center (CMCC) (if any) and the maintenance bases. It shall be a real time system and allow the data archiving system including, but not limited to, the following records:

- Record all events, alarms, and faults.
- Record in real time at least all input data used by the interlocking, signalling systems.
- Record in real time output from the Interlocking and signalling system.
- Local Maintenance Diagnosis System (LMDS) for the Interlocking (IXL) and Axle counter are the independent system that supports and allows the maintenance personnel tasks in the local mode. The main functions of both IXL and Axle counter maintenance diagnosis System are:
- Storing of the necessary information to reproduce the operator sequences
- Storing of the diagnosis information generated by the IXL and Axle Counter
- Real time reproduction of sequences in the maintenance record
- Real time reproduction of the diagnosis information.
- Reproduction of diagnosis information stored in the maintenance record
- Send diagnosis information of the Interlocking systems to the Operation Control Center (OCC) / Central Maintenance Control Center (CMCC).

The spare items of each subsystem as per OEM (Original equipment manufacturer) shall be provided at central maintenance store at each depot and local maintenance room on the section. The maintenance team shall be trained in multidisciplinary skills for all systems on section. The maintenance team shall be equipped with fully spare equipment-like cards, modules of each system for regular maintenance. The maintenance transport vehicle shall be provided to each maintenance team on section with maintenance tool kits.

The central maintenance store shall be managed to all systems and subsystems spare parts/ tools. Also, maintenance lab facility shall be provided at OCC/ Depot or at suitable location on the section. The lab will be equipped for diagnostic and testing of equipment as per the OEM (Original equipment manufacturer) guideline to rectify the faults and undertake minor repairs. For major faults (as per OEM maintenance manuals) in electronics card, modules, subsystem shall be sent to the OEM lab/workshop for replacement/rectification with proper documentation for the record. The maintenance team shall be monitored continuously essential wayside and subsystems equipments on section (Depot/ Station/ line side location etc.) to provide the corrective & preventive maintenance on time (before the failure occurs). It allows increasing the system availability and life cycle cost.

11.2.22 Adoptable Standard Specifications

The most important standards to be applied for Signalling & Train Control System are:

- EN 50126 for Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS)
- EN 50128 for Railway Applications- Communication, Signalling and Processing Systems - Software for Railway Control and Protection
- EN 50129 for Railways applications – Communications, signalling and processing systems – safety related electronic systems for signalling.
- EN 50159 for Railway Applications - Communication, Signalling and Processing Systems
- These define the RAMS (Reliability, Availability, Maintainability and Safety) requirements and requirements for designing the safety critical system. The other standards to be applied for communication system are:
- EN 301 515 for requirements for GSM operation on railways
- TS 102 610 for usage of the User to User Information Element
- TS 102 281 for detailed requirements for GSM operation on Railways
- EN 50122 for Railways Applications Fixed Installations - Electrical Safety, Earthing and the Return Circuit
- EN 50121 for Electromagnetic Compatibility
- EN 50125 for Railway Applications - Environmental Conditions for equipments
- EN 50155 for Railway Applications - Electronic Equipment Used on Rolling Stock
- EN 50153 for Railway applications - Rolling stock - Protective provisions relating to electrical

- EN 50238 for Railway applications – Compatibility between RS and train detection systems
- EN 50261 for Railway Applications - Mounting of Electronic Equipment. General Product Information
- EN 55264 for Railways fixed equipment – telecom wires for underground networks
- EN 302608 for Electromagnetic compatibility & spectrum (ERM) – Eurobalises
- EN 50102 for Degrees of protection provided by enclosures for Electrical equipment against external mechanical impacts
- EN12368 for Traffic control equipment - Signal heads
- EN 60068-2-11/27/30/64 for environmental testing of electronic equipment, components and electromechanical products to assess their ability to perform and survive under conditions such as transportation, storage, operational environments, extreme cold and heat.

All safety critical equipment shall be designed to conform to fail- safe principles in respect of RAMS, manufactured/OEM, validated to meet the safety Integrity level, in compliance with relevant latest version of international standards like British Standards, European Standards (EN), Indian Railway Standards (IRS), international Electromechanical Commission (IEC) standards, International Union of Railways (UIC), International organization for Specification (ISO) standards and other international standards that are widely accepted for HSR.

The transmission media and equipment needs to be in redundant configuration so that a single failure does not cause a hazardous failure. The system delays need to be taken into account. The more equipment and transmission required for movement authority, the more probable it is to have system delays and errors. Hence, there is an increased risk of having problems in train traffic caused by signalling systems, which needs to be considered in the system design phase. These delays also affect the safety of the railway system, when the train should be stopped in case of emergency.

The design of Signalling & Train Control system and its Operation & Maintenance shall, in general, comply with recommendation of NFPA 130 (Standards for fixed Guide Way-Transit and Passenger Rail System) This standard specifies fire protection and life safety requirements for underground, surface, and elevated fixed guideway transit and passenger rail systems.

11.2.23 Recommendation for Signalling & Train Control System

The Signalling and Train Control system shall provide the highest security level for means of an efficient Train Control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.

It is recommended that for SilverLine project from Thiruvananthapuram -Kasaragod Rail Corridor be equipped with ETCS level-2 that will provide integrated, efficient, standardized, proven and off-the-shelf world-class Signalling and Traffic Control Systems.

High speed rail line operation requires efficient and proactive train operation management. The Train Control Management System (TCMS) will provide the operator with an integrated and centralized control system that will ease the management of train operation on the Silver- Line and interface with depots especially in case of degraded and emergency situations. The Train control management System (TCMS) will provide real time supervision, monitoring and control functions on the complete Silver-Line and will allow proactive control from the OCC (or back-up OCC).

With ETCS level 2, it is proposed to duplicate Radio Block Center (RBC), in order to provide a high level of availability to the Signalling & Train Control system. With LTE/GSM-R and RBC being fully redundant, under no circumstances the Signalling Train Control system will totally be shut down. But in case equipment of ETCS Level-2 fails and becomes unavailable, the Fallback Block system can temporarily be worked for maintenance, safety and smooth operation with the help of line side signals provided at each interlocking.

ETCS Level-2 is the most proven train control system in the world and brings significant advantages in terms of low maintenance costs, safety, reliability, punctuality and traffic capacity. The ETCS level 2 cab signalling will ensure safe and efficient bi-directional train operation for both revenue and non-revenue trains during both revenue operation time (ROT) and maintenance working time (MWT), improving the work train movement safety and the MWT efficiency. Nowadays it is used in many parts of the Europe like Sweden, Belgium, Netherlands, Australia, Denmark, Italy, Spain, Switzerland, France, Romania, Greece, UK and Turkey. The use of ETCS is not limited to Europe. Mexico, South Korea, China, New Zealand, India and Taiwan also use ETCS functions of systems that were used previously in Europe.

The detailed project study provides the main design of Signalling and Train Control system for operation of the line with a design speed of 220 kmph, along with the associated sub system like Power supply, Surveillance system for monitoring and safety etc. In order to comply with the requirements of such a high-speed rail corridor, the proven system ETCS Level -2 is proposed for SilverLine project in Kerala.

In addition to the above, Indian railway is also going for modernisation of the signalling system with LTE in important routes. Indian Railways are processing to execute ETCS Level-2 with LTE in four different sections (Pilot projects) over Indian Railways. However, this work is under tendering stage now.

To handle increasing traffic, ensure passenger safety, and provide real-time multimedia information, a new communication system for high speed rail system is required. In the last decade, public networks have been evolving from voice-centric second-generation systems, e.g., Global System for Mobile Communications (GSM) with limited capabilities, to fourth generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for high speed rail to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability.

In order to comply with the requirements of such a high-speed rail corridor, the proven system ETCS Level -2 with LTE (Mobile Radio Communication System) is proposed to meet requirements of SilverLine. However, GSM-R system can be considered if the LTE (Railway) system is not matured at the time of executing this project.

Signalling & Train Control (ETCS level 2 with LTE) system of SilverLine project in Kerala would comprise of, but not limited to, following subsystems for smoother and safely train operation:

- ETCS level-2 System with LTE
- Interlocking System (EI/CBI)
- Electric Point Machine
- Track Vacancy Detection system (Axle counter)
- Automatic Train Supervision (ATS)
- Operation Control Center (OCC) with backup OCC
- Fall-Back Block System.

11.3 INTRODUCTION OF COMMUNICATION SYSTEM

The communication system is the backbone for Signalling & Train control system, SCADA system, Automatic Ticketing system, Safety & Security system etc. and provides communication service for information to Passenger, Administrative management, Operation & maintenance, Emergency control etc. requirements of high-speed train network.

Overcoming increasing traffic, ensuring passengers safety and security during their journey, improving travel comfort, providing real time multimedia information and access to social networks in stations or in motion are some of the key challenges that train/metro operators are facing today.

To meet all these requirements, train operators need to put in place broadband telecommunication networks, using a variety of technologies whether fixed or wireless. Heterogeneity of these networks is becoming a real headache for train operators and infrastructure managers: WI-FI, GSM-R, LTE, Satellite, 3G/4G networks.

Communication system is becoming a key component in the formulation of strategy by Railway operators and infrastructure managers. The system shall be cost effective and operationally efficient on the following domains:

- Operation of the Transportation system
- Safety and Security
- Passenger experience

Communications also contribute to the brand image of system operators and in some cases may even add to revenue (Utilities telecom business model).

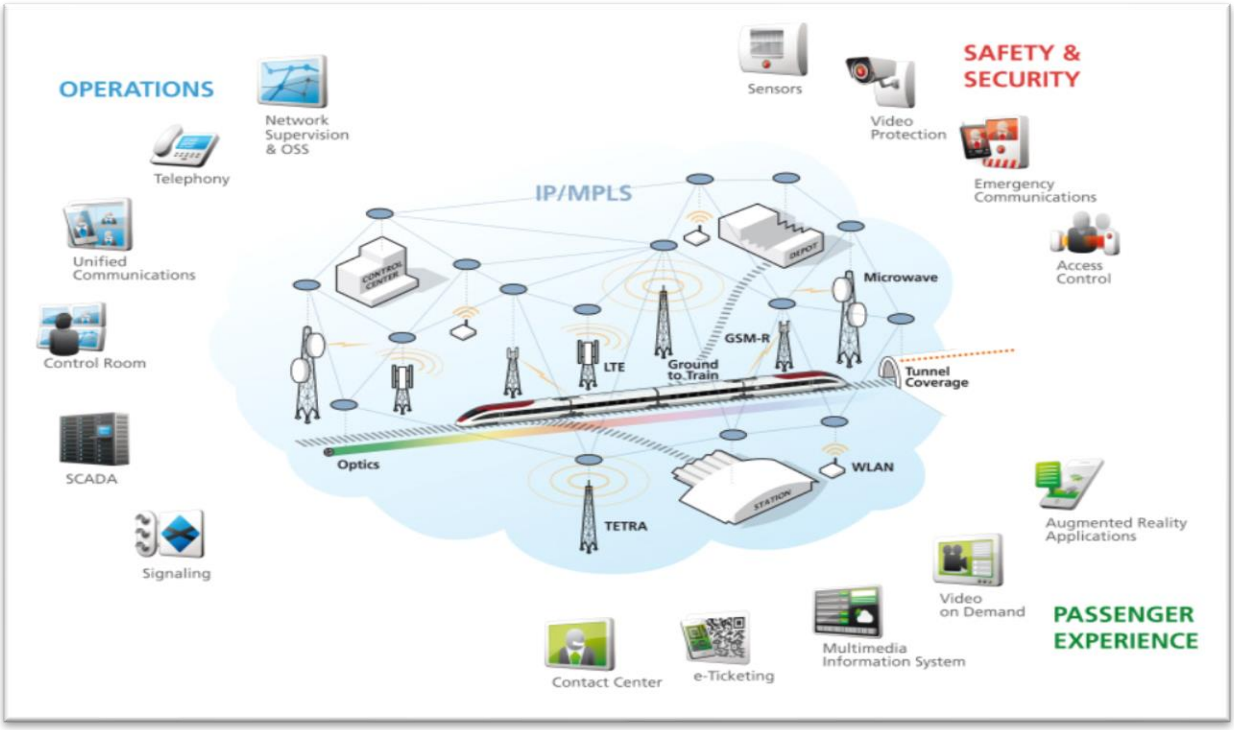


Figure 11-31: Communication as the backbone for converged rail operations

The selection of an optimal wireless communication system for Railways and metro system need to consider many performance parameters and service attributes such as voice support, vital traffic, priority, availability, frequency band, commercial maturity. The figure below compares these different technologies in terms of performance and industrial support.

Table 11-8: Wireless technology comparison

Service	GSM-R	TETRA	P25	Wi-Fi	LTE
Operational Voice support	+	+	+	VoIP	VoIP
Broadband Data Support	<10kb/s	<10kb/s	<100kb/s	<10kb/s	<10kb/s
All IP (Native)	-	-	-	+	+
P2T/ Call set up Time	1 to 5 s	250ms	800ms	100ms	100ms
Handover Mechanism	Standard	Standard	Standard	Proprietary	Standard
Priorities/ Pre-emption	+	+	+	3 Levels/ No	9 Levels/ Yes
Choice for operating Frequency	900MHz UIC	400MHz PMR	700MHz + VHF	2.4/ 5.x GHz	400MHz to 3.5GHz

Global System for Mobile Communications (GSM-R) (2G) technically has limited capabilities compared to fourth generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system, which provides improved capacity and capability in future.

LTE is the future railway communication system. It is clear that LTE is a major improvement over the existing mobile technologies both in terms of network capacity, bandwidth and other specific railway requirements, like latency or reliability. Some of the other challenges like RAMS. Reliability, Availability Maintainability and Safety (RAMS) requirements, end to end Quality of Service (QoS) requirements, system performance in high speed scenarios, communication system deployment strategy, and system backward compatibility as well as the future system features for delivering high speed railway services.

Nevertheless, meeting the consumer demand for on train broadband services, while supporting extremely high bandwidth consuming applications such as on train Closed Circuit Television (CCTV) surveillance, is still a major challenge that require a closer look before planning and dimensioning the LTE-R network. LTE-R system is being developed in Europe, South Korea and China.

World’s First LTE-Railway Service started on new High-Speed Rail line from Wonju-Gangneung by Korea Rail Network Authority (KRNA) in 21st December 2017. The Samsung and Korean telecom firm KT announced that the LTE-Railway (LTE-R) network for the new Wonju-Gangneung high-speed train line is now live. The activation represents the world’s first application of LTE-R technology to a high-speed train, with the new line travelling up to 250 kmph. The network will include key features such as Mission-Critical Push-to-talk (MCPTT) based on the 3GPP standards. The new Wonju-Gangneung line, operated by the Korea Rail Network Authority (KRNA), spans 120 km long. The LTE-R network is applied across the line’s seven stations, while the solution is interoperable with legacy Trunked Radio System (TRS), Very High Frequency (VHF) systems, and the National Public-Safety LTE (PSLTE) network. This project is intended to serve as a model for future LTE-R deployments and help further define LTE-R standardization efforts. The deployment will be a prototype for future LTE-R deployments, adding to progress in LTE-R standardization and definition.

Further, LTE is being used in China on the Zhengzhou Metro Line 1, where it provides wireless ground-to-train voice, data and video channels, and on Shuo Huang Railway (the freight operator in China) between the multiple locomotives (slave and driver) of the freight trains using 1800 MHz LTE TDD network, which has resulted in significant capacity augmentation of the freight line.

LTE-R based ETCS Level-2 signalling system is still on trial in some railways in the world. LTE- Railway based ETCS -Signalling Train control System has not come to full-fledged proven system. If LTE-Railway System does not mature and is not fully accepted worldwide, by that time Silver-Line rail corridor work is executed, GSM-R can be considered instead of LTE-R for Silver Line project in Kerala.

11.3.1 Future Railway Communications System

High-speed railways improve the quality of rail services, yield greater customer satisfaction, and help to create socioeconomically balanced societies. This highly efficient transport mode creates significant challenges in terms of investment, technology, industry, and environment. To handle increasing traffic, ensure passenger safety, and provide real-time multimedia information, a new communication system for HSR is required. In the last decade, public networks have been evolving from voice-centric second-generation systems, e.g., Global System for Mobile Communications (GSM) with limited capabilities, to fourth generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-Railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability. With the rapid development of HSRs, a reliable broadband communications system is essential for different HSR components, such as train control and safety-related communications.

Since 2014, a project of the International Union of Railways or Union Internationale des Chemins de Fer (UIC), known as the Future Railway Mobile Communication System (FRMCS), has started to assess and shape the future of HSR mobile communications and to identify suitable candidate technologies to use, once the currently used GSM-R has become obsolete. HSR applications have strict requirements for quality-of-service (QoS) measures, such as data rate, transmission delay, and bit error rate (BER). Due to these factors as well as a desire to use mature and low-cost technology, HSR communications generally use off-the-shelf technologies and add applications to meet specific services and demands.

A new system is thus required to fulfil HSR operational needs, with the capability of being consistent with LTE, offering new services. The selection of a suitable wireless communication system for HSRs needs to consider such issues as performance, service attributes, frequency band, and industrial support. Compared with third generation (3G) systems, 4G LTE has a simple flat architecture, high data rate, and low latency, making it an acknowledged acceptable bearer for real-time HSR applications. In view of the performance and level of maturity of LTE, LTE-railway (LTE-R) will likely be the next generation of HSR communication systems and the future vision for HSR wireless technologies will thus rely on it. The below table shows the parameter of GSM-R and LTE-R system as:

Table 11-9: System Parameters of GSM-R, LTE and LTE-R

Parameter	GSM-R	LTE	LTE-R
Frequency	Uplink: 876-880 MHz; Downlink: 921-925 MHz	800 MHz, 1.8 GHz, 2.6 GHz	450 MHz, 800 MHz, 1.4 GHz, 1.8 GHz
Bandwidth	0.2 MHz	1.4-20 MHz	1.4-20 MHz
Modulation	GMSK	QPSK/ M-QAM/ OFDM	QPSK/16-QAM
Call Range	8 km	1-5 km	4-12 km
Cell Configuration	Single sector	Multisector	Single sector
Peak data rate, downlink/uplink	172/172 Kbps	100/50 Mbps	50/10 Mbps

Parameter	GSM-R	LTE	LTE-R
Peak spectral efficiency	0.33 bps/Hz	16.32 bps/Hz	2.55 bps/Hz
Data transmission	Requires voice call connection	Packet switching	Packet switching (UDP data)
Packet retransmission	No (serial data)	Yes (IP packets)	Reduced (UDP packets)
MIMO	No	2x2, 4x4	2x2
Mobility	Max. 500 km/hr	Max.350 km/hr	Max.500 km/hr
Handover success rate	≥ 99.5%	≥ 99.5%	≥ 99.9%
Handover procedure	Hard	Hard/ soft	Soft: no data loss
All IP (native)	No	Yes	Yes

GSM-R System Limitations:

Although the popularity of GSM-R is still growing, increasing interference from public networks is hampering the use of GSM-R, while the assigned radio frequencies limits its capacity. Several limitations are summarized in the following.

- **Interference:** The interference between GSM-R and other public networks increases because both railway and public operators want to have good coverage along the rail tracks. Instead of cooperating in network planning, railway and public operators fight for the coverage. The interference could result in severe impairment of voice and data communications as well as network loss over several hundred meters of track. Theoretically, such interference can be avoided if public operators do not use frequency bands adjacent to those of GSM-R for the areas close to rail tracks; however, this is not well implemented in practice. In the future, interference may increase owing to the growth of GSM-R network deployment and the potential growth of public networks.
- **Capacity:** The 4-MHz bandwidth of GSM-R can support 19 channels of 200-KHz width. This is sufficient for voice communication, as voice calls are limited in time and do not occupy resources continuously. However, the current capacity turns out to be insufficient for the next-generation railway system, where each train needs to establish a continuous data connection with a Radio

Block Center (RBC), and each RBC connection needs to constantly occupy one time slot. The radio capacity can be increased by using more spectrum resources.

- **Capability:** As a narrow-band system, GSM-R cannot provide advanced services and adapt to new requirements. The maximum transmission rate of GSM-R per connection is 9.6 kb/s, which is sufficient only for applications with low demands; message delay is in the range of 400 m, which is too high to support any real-time application and emergency communication. The future services of HSRs such as real-time monitoring require a wide-band system to have larger data rate and short delay.

Due to the above limitations, GSM-R must eventually evolve to eliminate revealed shortcomings. LTE-R, which could be based on the LTE standard, is a likely candidate to replace GSM-R in the future for the following reasons:

- LTE has many advantages over GSM in terms of capacity and capabilities.
- As a fully packet-switched-based network, LTE is better suited for data communications.
- LTE offers a more efficient network architecture and thus has a reduced packet delay, which is one of the crucial requirements for providing ETCS messages.
- LTE has a high throughput radio access, as it consists of a number of improvements that increase spectral efficiency, such as advanced multiplexing and modulation.
- LTE is also a well-established and off-the-shelf system and provides standardized interworking mechanisms with GSM.

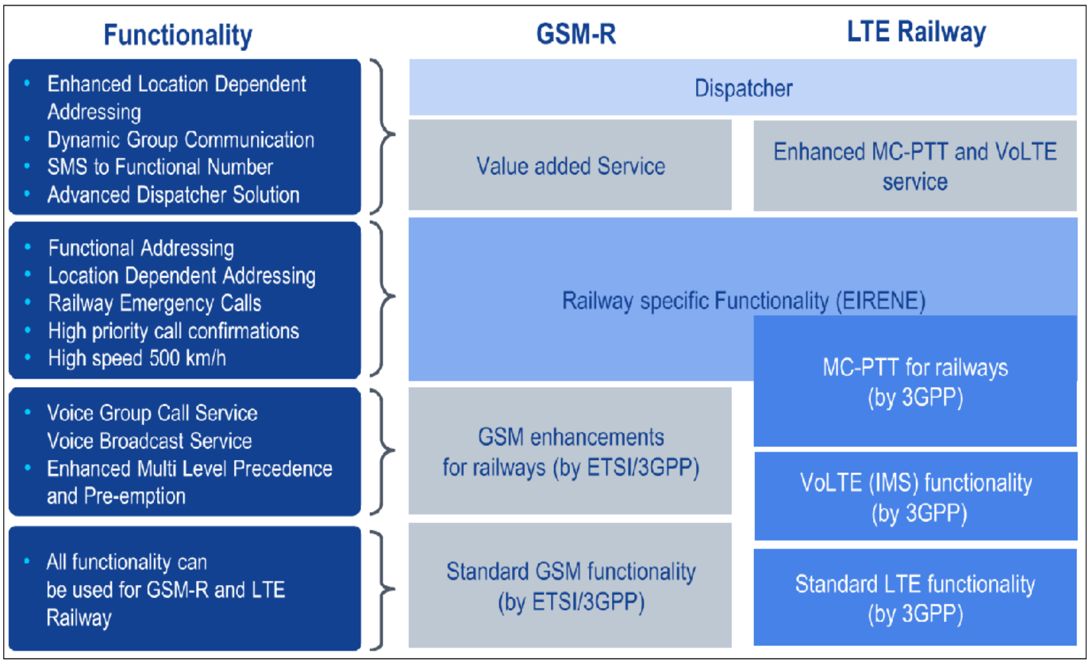

Functionality
GSM-R
LTE Railway
Enhanced Location Dependent Addressing
Dynamic Group Communication
SMS to Functional Number
Advanced Dispatcher Solution
Functional Addressing
Location Dependent Addressing
Railway Emergency Calls
High priority call confirmations
High speed 500 km/h
Voice Group Call Service
Voice Broadcast Service
Enhanced Multi Level Precedence and Pre-emption
All functionality can be used for GSM-R and LTE Railway
Dispatcher
Value added Service
Enhanced MC-PTT and VoLTE service
Railway specific Functionality (EIRENE)
MC-PTT for railways (by 3GPP)
GSM enhancements for railways (by ETSI/3GPP)
VoLTE (IMS) functionality (by 3GPP)
Standard GSM functionality (by ETSI/3GPP)
Standard LTE functionality (by 3GPP)

Figure 11-32: GSM-R Evolution towards LTE-Railway

A schedule of standardization and establishment of LTE-R is shown in Figure 11-33. The UIC is expected to complete operation and functional requirements determination by 2017. In China, the development of LTE-R also has been widely discussed and scheduled by the government. The first LTE-R network of China is scheduled for 2020; a time frame of LTE-R in China is presented in Figure 11-33 .

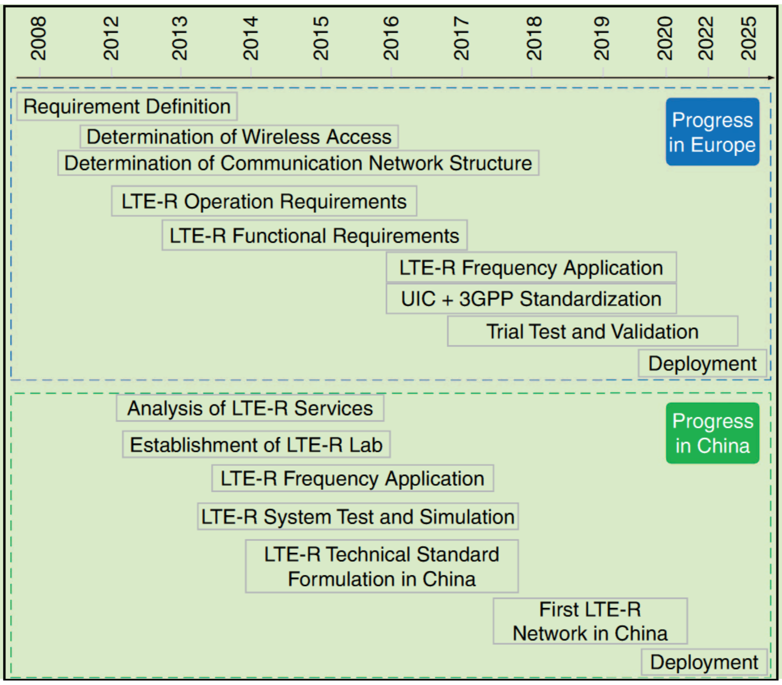


Figure 11-33: Progress chart of LTE-R standardization and establishment

11.3.2 LTE-R System Description

To provide improved and more efficient transmission for HSR communications, it is vital to consider frequency and spectrum usage for LTE-R. HSRs are important strategic infrastructure, and, in some countries, this argument is being leveraged to convince governments that large spectrum chunks need to be allocated specifically for it. Some industry bodies, including the European Railway Agency (ERA), China Railway, and UIC, are working to secure spectrum allocation for HSR use. Currently, most LTE systems work at the bands above 1 GHz, such as 1.8, 2.1, 2.3, and 2.6 GHz, although 700–900-MHz bands are also used in some countries. Large bandwidth is available in the upper bands, giving a higher data rate, whereas lower frequency bands offer longer distance coverage.

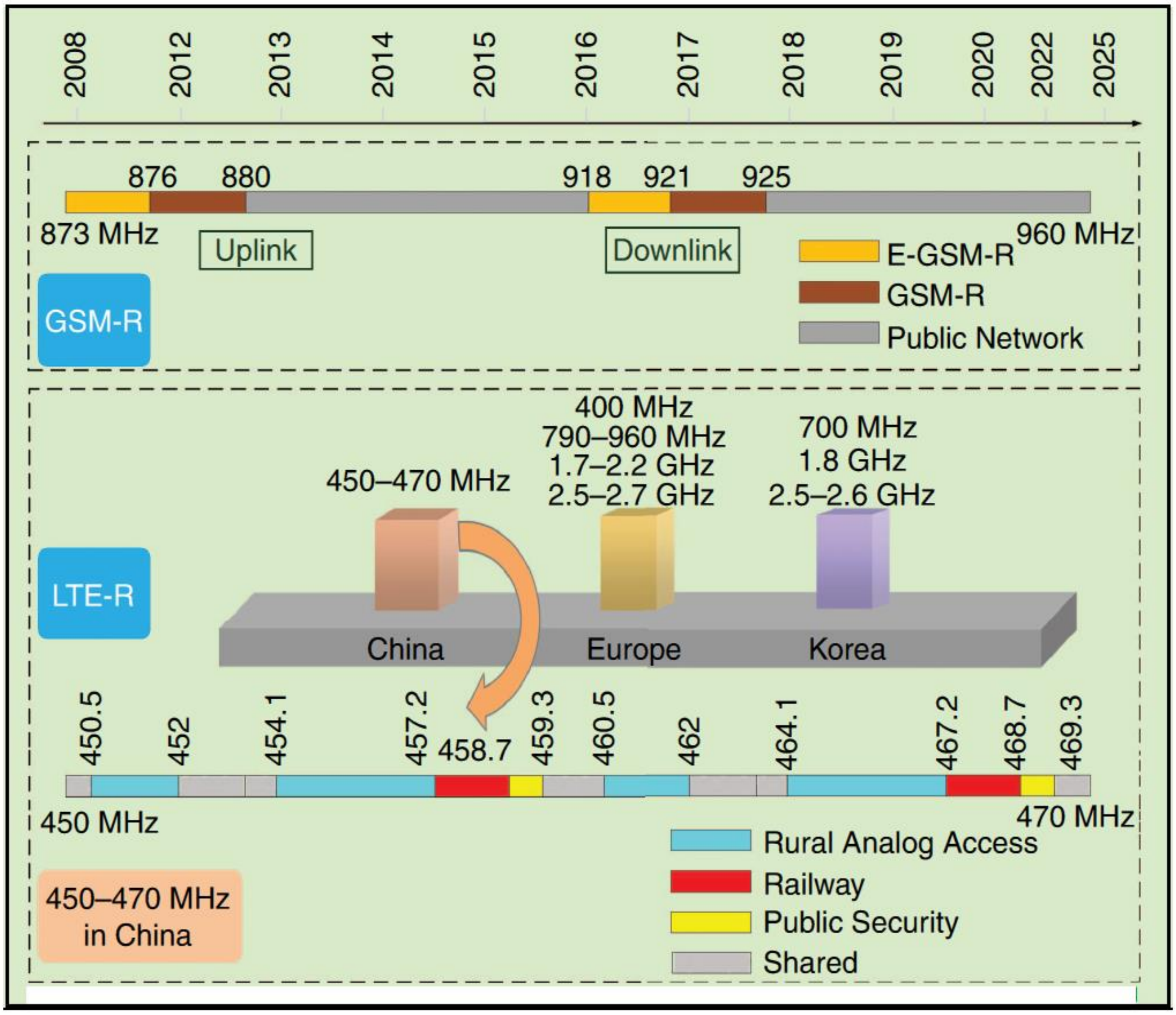


Figure 11-34: Allocation of Frequency Bands

Figure 11-34 summarizes the possible frequency bands for LTE-R in China, Europe, and Korea. As a high-frequency band has larger propagation loss and more severe fading, the radius of an LTE-R cell would be bands to overcome problems of capacity. Figure 11-34 presents the detailed frequency allocation of 450– 470 MHz in China, and it is feasible to allocate enough bandwidth for LTE-R within this band. However, the selection of frequency band depends on government policy and differs by country.

Table 11-10: Comparison of Frequency Band

Parameters	400 MHz	700 MHz
Propagation Characteristics	Radio wave travels larger distance due to comparatively less path loss resulting in larger coverage	Radio wave travels relatively smaller distance due to comparatively more path loss resulting in less coverage
Wall penetration loss	Less penetration loss leading to better in-building coverage	Relatively more penetration loss leading to relatively weaker in-building coverage
Antenna size and gain	Larger sized antennas with less gain. MIMO may not be feasible with antenna constraints	Relatively smaller sized antennas with higher gains. 2X2 MIMO using cross-polarization is feasible at the base station and user terminal
Interference	Creates more interference as the signal travels larger distance, hence suitable for larger cell sizes. However, down tilt of antennas help in reducing interference and relatively more capacity	Creates relatively less interference making it more suitable in small cells. In cases where user density is high, the differences may not be significant except the advantages of using low frequencies for in-building scenarios
Usage scenario	Larger cell sizes with sparse user distribution	Smaller cells with dense user distribution
Sparse user distribution scenario	More cell sites required	Less cell sites required
Economy of scale and cost	Higher cost due to non-availability of commercial eNBs and UEs	Lower cost due to availability of commercial eNBs and UEs

Parameters	400 MHz	700 MHz
Power Amplifier	Relatively lower rating PA is enough, helps to reduce cost significantly	Relatively higher rating PA is required, may increase the cost significantly

11.3.2.1 First LTE-R System for Railway

The World's First LTE-R for 250 kmph high speed railway is implemented in republic of Korea on new line Wonju- Gangneung on 21st December 2017 , Line operated by the Korea Rail Network Authority (KRNA), spans 120 kms long. LTE-R wireless communication System is used for Train Operation and maintenance. Frequency allocation for this project is 700 MHz band (UL-718-728 MHz and DL 773-783 MHz). LTE-R system supports railway specific wireless service (Voice, Video, Large Data) between stations and trains based on 4G Technology LTE.

The Korea Railway verification of 23 test items was done at Test- Bed on KTX Honam Line (34.3 km, Iksan to Jeongeup including Noryeong Tunnel 4.3 km). The Standardization of this LTE-R standards for Conventional and High -Speed rail service with Telecommunications Technology Association (TTA) in Korea.

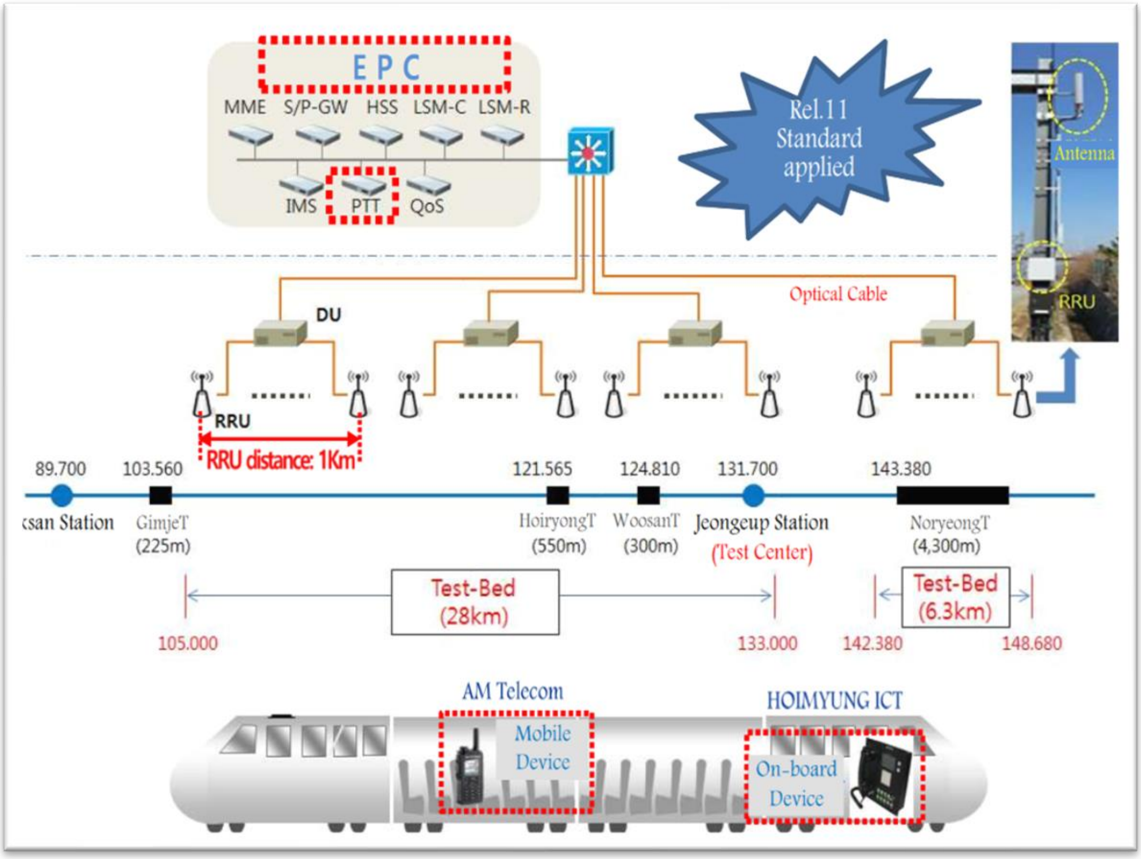
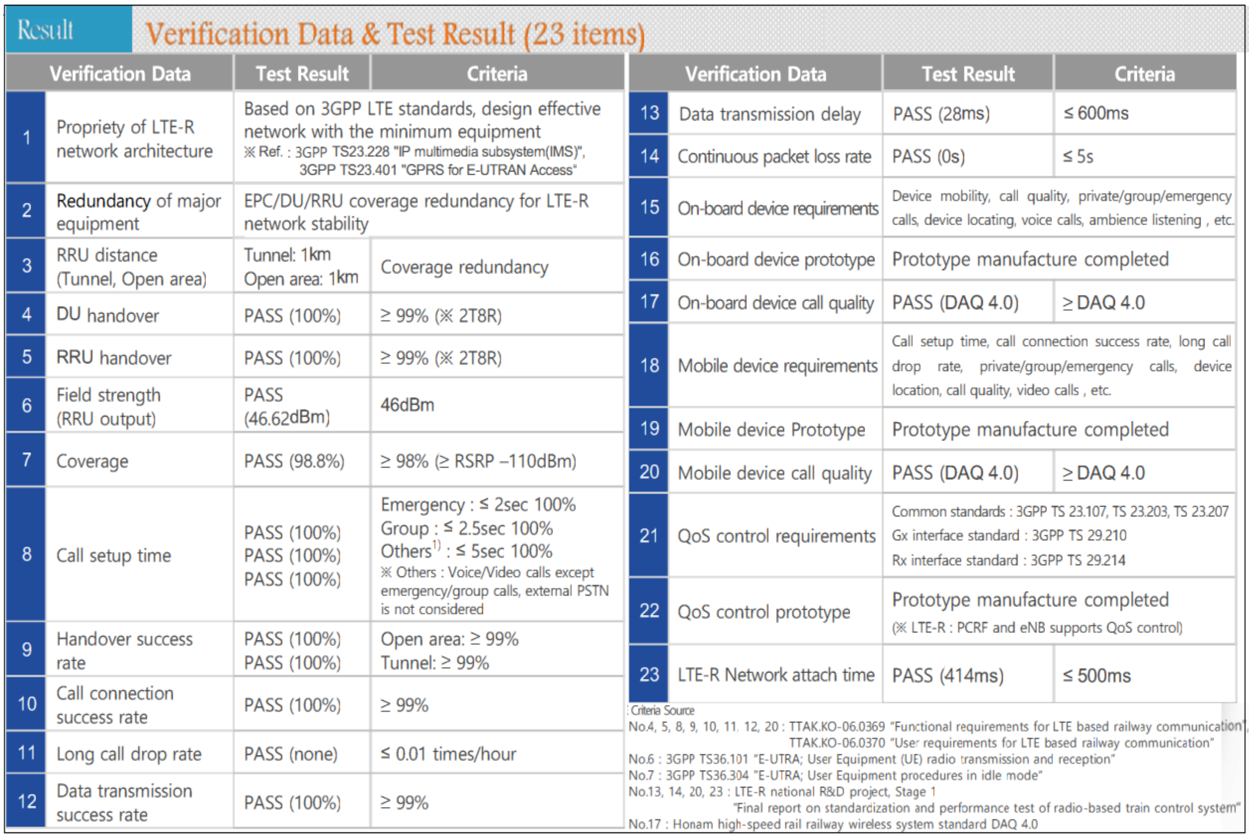


Figure 11-35: Testbed for testing & verification of LTE-R

The Korea Railway testing and verification with Domestic Standards (TTA) for LTE based railway Communication system for Conventional and High-speed rail. The flexibility in High Speed Moving testing environment is speed of 250 kmph for testing. LTE-R assurance of 98% service coverage with average data throughput DL-40 Mbps and UL- 20 Mbps. The 23-test item result is mentioned in Table 11-11.

Table 11-11: Verification data & test results



Result

Verification Data & Test Result (23 items)

No.	Verification Data	Test Result	Criteria
1	Propriety of LTE-R network architecture	Based on 3GPP LTE standards, design effective network with the minimum equipment ※ Ref. : 3GPP TS23.228 "IP multimedia subsystem(IMS)", 3GPP TS23.401 "GPRS for E-UTRAN Access"	
2	Redundancy of major equipment	EPC/DU/RRU coverage redundancy for LTE-R network stability	
3	RRU distance (Tunnel, Open area)	Tunnel: 1km Open area: 1km	Coverage redundancy
4	DU handover	PASS (100%)	≥ 99% (※ 2T8R)
5	RRU handover	PASS (100%)	≥ 99% (※ 2T8R)
6	Field strength (RRU output)	PASS (46.62dBm)	46dBm
7	Coverage	PASS (98.8%)	≥ 98% (≥ RSRP –110dBm)
8	Call setup time	PASS (100%) PASS (100%) PASS (100%)	Emergency : ≤ 2sec 100% Group : ≤ 2.5sec 100% Others[1] : ≤ 5sec 100% ※ Others : Voice/Video calls except emergency/group calls, external PSTN is not considered
9	Handover success rate	PASS (100%) PASS (100%)	Open area: ≥ 99% Tunnel: ≥ 99%
10	Call connection success rate	PASS (100%)	≥ 99%
11	Long call drop rate	PASS (none)	≤ 0.01 times/hour
12	Data transmission success rate	PASS (100%)	≥ 99%
13	Data transmission delay	PASS (28ms)	≤ 600ms
14	Continuous packet loss rate	PASS (0s)	≤ 5s
15	On-board device requirements	Device mobility, call quality, private/group/emergency calls, device locating, voice calls, ambience listening , etc.	
16	On-board device prototype	Prototype manufacture completed	
17	On-board device call quality	PASS (DAQ 4.0)	≥ DAQ 4.0
18	Mobile device requirements	Call setup time, call connection success rate, long call drop rate, private/group/emergency calls, device location, call quality, video calls , etc.	
19	Mobile device Prototype	Prototype manufacture completed	
20	Mobile device call quality	PASS (DAQ 4.0)	≥ DAQ 4.0
21	QoS control requirements	Common standards : 3GPP TS 23.107, TS 23.203, TS 23.207 Gx interface standard : 3GPP TS 29.210 Rx interface standard : 3GPP TS 29.214	
22	QoS control prototype	Prototype manufacture completed (※ LTE-R : PCRF and eNB supports QoS control)	
23	LTE-R Network attach time	PASS (414ms)	≤ 500ms

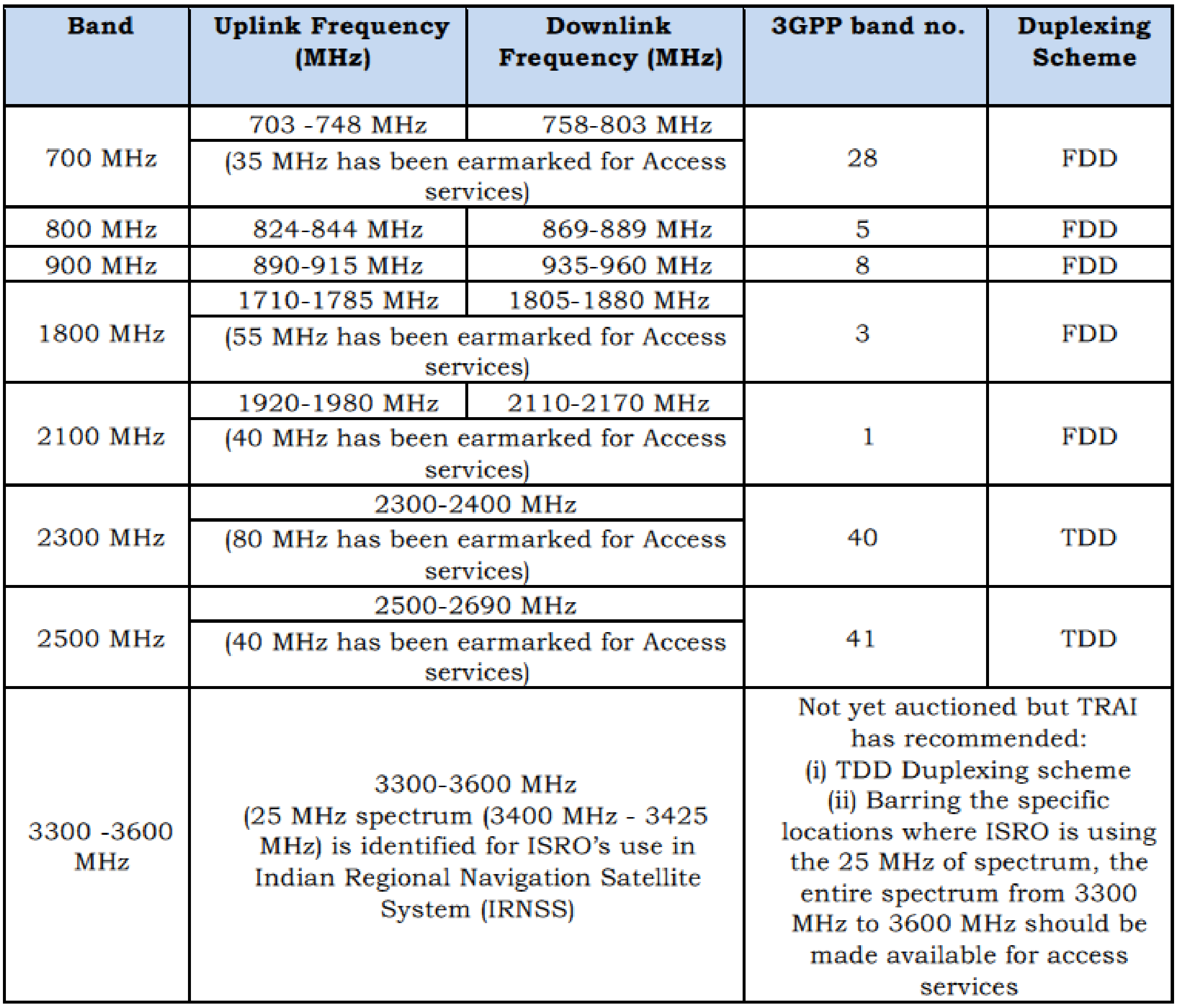
: Criteria Source
No.4, 5, 8, 9, 10, 11, 12, 20 : TTAK.KO-06.0369 "Functional requirements for LTE based railway communication",
TTAK.KO-06.0370 "User requirements for LTE based railway communication"
No.6 : 3GPP TS36.101 "E-UTRA; User Equipment (UE) radio transmission and reception"
No.7 : 3GPP TS36.304 "E-UTRA; User Equipment procedures in idle mode"
No.13, 14, 20, 23 : LTE-R national R&D project, Stage 1
"Final report on standardization and performance test of radio-based train control system"
No.17 : Honam high-speed rail railway wireless system standard DAQ 4.0

11.3.3 Spectrum requirement and availability in India:

Presently, spectrum assignment for International Mobile Telecommunications (IMT) services in India is being done through auction process and the spectrum sold is liberalized (technology agnostic) i.e. the service provider has the freedom to decide the technology to be deployed in the given spectrum band. With the passage of time, several spectrum bands have been earmarked for services in India.

Table 11-12 provides the details of these spectrum bands.

Table 11-12: Spectrum bands earmarked for IMT services in India



Band	Uplink Frequency (MHz)	Downlink Frequency (MHz)	3GPP band no.	Duplexing Scheme
700 MHz	703 -748 MHz (35 MHz has been earmarked for Access services)	758-803 MHz	28	FDD
800 MHz	824-844 MHz	869-889 MHz	5	FDD
900 MHz	890-915 MHz	935-960 MHz	8	FDD
1800 MHz	1710-1785 MHz (55 MHz has been earmarked for Access services)	1805-1880 MHz	3	FDD
2100 MHz	1920-1980 MHz (40 MHz has been earmarked for Access services)	2110-2170 MHz	1	FDD
2300 MHz	2300-2400 MHz (80 MHz has been earmarked for Access services)		40	TDD
2500 MHz	2500-2690 MHz (40 MHz has been earmarked for Access services)		41	TDD
3300 -3600 MHz	3300-3600 MHz (25 MHz spectrum (3400 MHz - 3425 MHz) is identified for ISRO's use in Indian Regional Navigation Satellite System (IRNSS)		Not yet auctioned but TRAI has recommended: (i) TDD Duplexing scheme (ii) Barring the specific locations where ISRO is using the 25 MHz of spectrum, the entire spectrum from 3300 MHz to 3600 MHz should be made available for access services	

Indian Railway (IR) has requested to reserve 15 MHz (paired) in 700 MHz band and initially assign 10 MHz (paired) for LTE based communication corridor along their network for Train-ground and Train-Train Communication. The 700 MHz band is being used worldwide for deployment of 4G due to its excellent propagation characteristics and therefore it is one of the most sought-after band for deployment of LTE. LTE device ecosystem is developing fast in this band.

Indian Railway (IR) has further clarified that the bandwidth requirement of 10 MHz in 700 MHz frequency band is for data usage needs for following safety and security applications/facilities:

- Mission Critical Passenger Safety Services & Applications through a Modern Train Control System for Railway Signalling system on IR. Modern Train control will augment train carrying capacity on Railway network because of increased speed and less fixed distance between the trains. This will allow a greater number of trains to be handled safely on the same fixed infrastructure.

- Video Surveillance (Live feed) through CCTV networks in trains along with Video Analytics for passenger Security.
- Faster data network Communication for voice, video and other related applications like IoT based Asset reliability, Monitoring and Train and way side telemetry through Mobile communications.

Long Term Evolution (LTE) is 4th Generation (4G) Mobile Communication System and is emerging as Global Standard for all new Train Control and Railway Signalling applications replacing the incumbent 2nd Generation (2G) GSM-R technology and is likely to see the broadest deployment of any new wireless technology over the next decade in Railway Safety, Security and Passenger experience applications.

Installing an Ultra-high-speed LTE based communication system for railway network would cater to the current and future data and voice needs for Train-Ground and Train-Train communication for improved train operations, passenger safety and passenger security services and remote rail asset monitoring & management. The applications of LTE can be classified under the following three broad categories:

- Passenger safety & service:
    - Advanced Signalling systems like European Train Control System (ETCS) Level 2.
    - Emergency communications from train to control, train to stations and between train to train, etc.
    - Advanced signalling systems allow more trains to run across a given point or segment of the track which effectively increase the carrying capacity (throughput) of the same fixed civil and electrical infrastructure.
- Surveillance: Live surveillance camera feeds from trains will ensure security of passengers coupled with video analytics, this can help in prevention and detection of crime, not only in Railways network but also outside the peripheral areas.
- Internal improved Railway management:
    - Staff communication system.
    - Remote monitoring of Railways asset to improve their availability.

The International Telecommunication Union- Radiocommunication Sector (ITU-R) has identified the digital dividend spectrum in the frequency band 698-806 MHz for IMT in Region-3 (Asia-Pacific). This frequency range can provide effective mobile broadband services for Public Safety network and thus is most suitable for Railways requirement in India.

Adoption of 700 MHz frequency spectrum is growing across world’s railways because of its inherent advantages such as wide coverage, low Capex, efficient network utilization etc. Another driving force is the ability in 700 MHz spectrum of LTE to provide efficient high speed, low latency, low setup time, and high-security data connectivity, which is the precondition to provide multimedia and especially mission critical multimedia communication for safety and security application on Railways.

The bandwidth requirements in 700 MHz depend on data usage needs and capacity to carry projected amount of data. Railway envisages following applications/facilities which will fuel growth in data usage on deploying LTE technology in 700 MHz:

- Mission Critical Passenger Safety Services & Applications through ETCS Level 2
- Video Surveillance (Live Feed) through CCTV cameras in trains along with Video Analytics for Passenger Security.
- Faster data network Communication for voice, video and other related application.
- More network-enabled devices (IoT based Asset reliability Monitoring).
- Providing Wi-Fi facility in trains.
- Train and way side Telemetry through Mobile communications.

11.3.4 LTE-R Architecture for High Speed Railway Communication

It is a digital communications platform designed for Professional Mobile Radio (PMR) users. It allows the integration of several radio technologies and provides a unified service supporting different communications needs in the transport sector and specifically in the rail market.

The final design of the LTE system must be adapted to the requirements of every project, and may vary according to the next aspects:

- Data traffic model for the applications to run over LTE. Typically, it is necessary to establish the average traffic load in the cell, and what is the minimum capacity to guarantee at the cell edge.
- Number of users who will require broadband applications and expected concentration of users per cell.
- Geographical features of the area to cover in order to provide the most accurate geographic coverage analysis.

In LTE terminology, base stations are also called eNodeB. All eNodeB deployed conform the Radio Access Network or RAN, also called E-UTRAN (Evolved Universal Terrestrial Radio Access) by 3GPP standard. The eNodeB are installed in specific physical sites to provide RF coverage to a geographical area. They coordinate the radio reception and transmission from/to user equipment, as well as the connectivity through backbone network with control node.

LTE System architecture is shown in next figure. It is a flat model with a simple hierarchy organized in four levels:

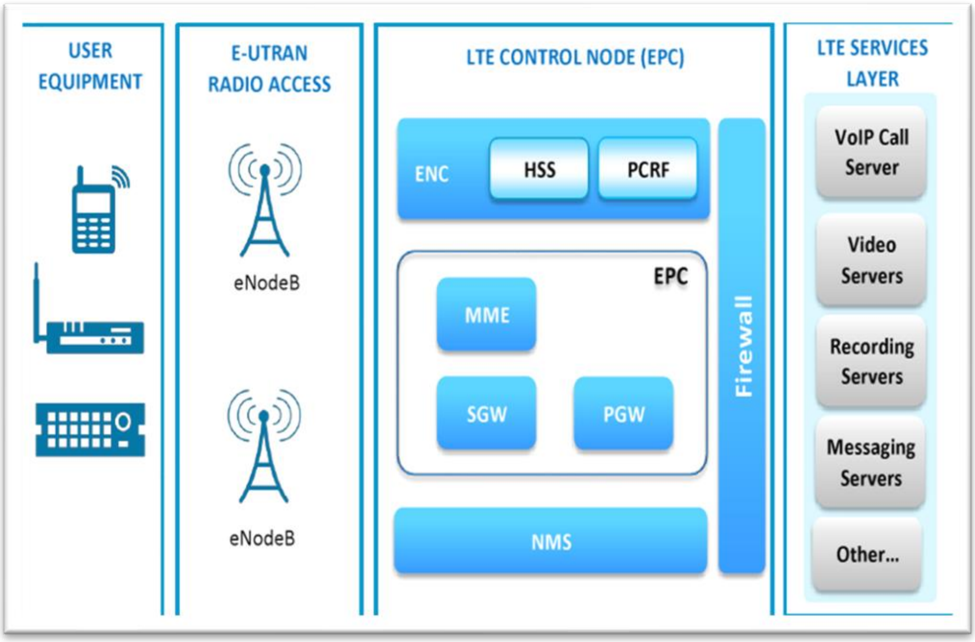
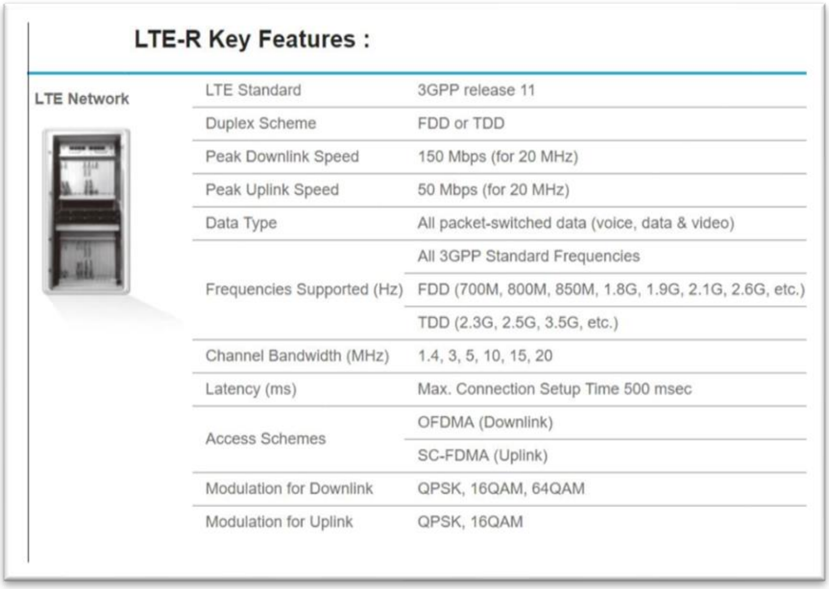


Figure 11-36: LTE simple architecture

- User Equipment (UE) - User Equipment can adopt different form-factors depending on its purpose in the critical operation. Some examples: LTE- Mobile Handset, embedded LTE modules, vehicular equipment and of course, on-board rail units compliant with the most demanding railway regulations.
- Radio Access Network, also called LTE terminology as E-UTRAN (Evolved Universal Terrestrial RAN), where base stations or eNodeB (Evolved NodeB) are the key entities responsible to manage radio interface and provide RF coverage.
- Central Control Node also called Evolved Packet core (EPC). LTE control node is responsible for routing IP data between base stations and external IP services. In 3GPP terminology, it is called Evolved Packet Core and it is the key entity of the LTE core network. The EPC includes all the entities for the control and routing of IP communications. All these logical entities as well as the rest of elements are configured and monitored through the Network Management System or NMS. 3GPP establishes that the key entities of EPC are the following:
- Mobility Management Entity (MME), an MME is the main control entity for the E-UTRAN. It communicates with an HSS for user authentication and user profile download and provides UEs with EPS Mobility Management (EMM) and EPS Session Management (ESM) functions using NAS signalling.
- Serving Gateway (SGW), is the entity responsible to route the user data traffic between eNodeB and PGW. It is responsible to create, manage and disable data bearers according to predefined rules of quality of service.

- Packet Data Network Gateway (PGW), as the entity acting as user data traffic gateway from LTE infrastructure towards external IP networks implementing backend user services. It is organized in several functional entities that implements the functionality specified by 3GPP standard specifications:
- Evolved Node Controller (ENC), responsible for controlling the access to LTE system and implementing authorization methods for user equipment, as well as managing the quality of service policies and priorities in EPC. This entity integrates two key modules: HSS (Home Subscriber System) for LTE user provisioning and registration, and PCRF (Policy Charging Rules Function), to define access policies to LTE services. It also centralizes other control functions like synchronization tasks for all hardware entities in the infrastructure as well as the collection of statistical information.
- Network Management System (NMS) Server, as responsible module for the network management, configuration of any equipment, subscriber management, alarms monitoring, etc.
- Firewall is the key door of the system for any kind of IP connection from/to external networks.
- Other physical elements required for the installation and operation of the system like for instance: - EPC chassis and switches, required to interconnect hardware modules in the control node among them, as well as to establish connections with base stations. The Cabinets, power supply sources and cabling etc.
- Service layer, that may be based in solutions provided by LTE-R solutions.



LTE-R Key Features :

LTE Network	LTE Standard	3GPP release 11
	Duplex Scheme	FDD or TDD
	Peak Downlink Speed	150 Mbps (for 20 MHz)
	Peak Uplink Speed	50 Mbps (for 20 MHz)
	Data Type	All packet-switched data (voice, data & video)
	Frequencies Supported (Hz)	All 3GPP Standard Frequencies
		FDD (700M, 800M, 850M, 1.8G, 1.9G, 2.1G, 2.6G, etc.)
		TDD (2.3G, 2.5G, 3.5G, etc.)
	Channel Bandwidth (MHz)	1.4, 3, 5, 10, 15, 20
	Latency (ms)	Max. Connection Setup Time 500 msec
	Access Schemes	OFDMA (Downlink)
		SC-FDMA (Uplink)
	Modulation for Downlink	QPSK, 16QAM, 64QAM
	Modulation for Uplink	QPSK, 16QAM

Figure 11-37: LTE-R Key Feature

Standard LTE includes a core network of evolved packet core (EPC) and a radio access network of Evolved Universal Terrestrial Radio Access Network (E-UTRAN). The Internet protocol (IP)-based EPC supports seamless handovers for both voice and data to cell towers, and each E-UTRAN cell will support high data and voice capacity by high-speed packet access (HSPA). As a candidate for the next-generation communication system of HSR, LTE-R inherits all the important features of LTE and provides an extra radio access system to exchange wireless signals with onboard units (OBUs) and to match HSR-specific needs.

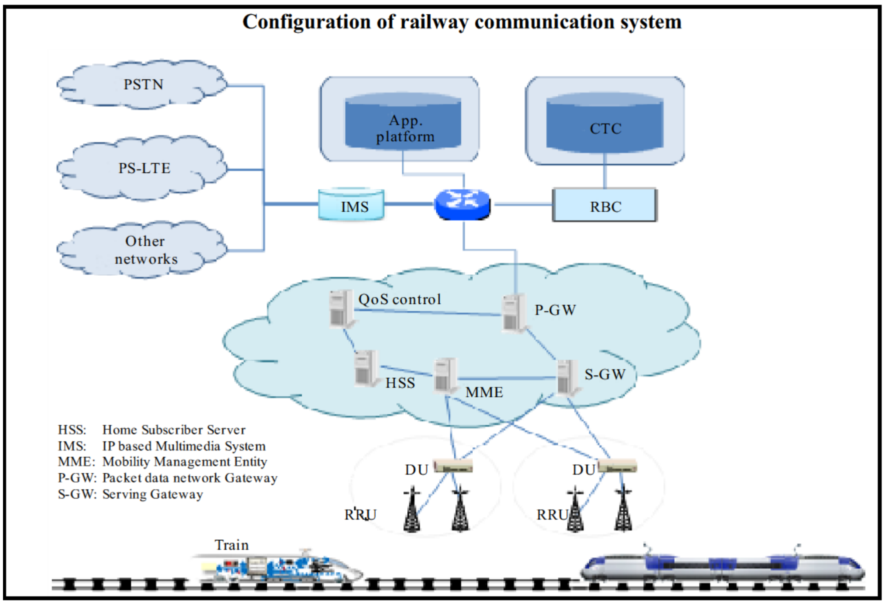

Configuration of railway communication system
PSTN
PS-LTE
Other networks
App. platform
CTC
IMS
RBC
QoS control
P-GW
HSS
MME
S-GW
HSS: Home Subscriber Server
IMS: IP based Multimedia System
MME: Mobility Management Entity
P-GW: Packet data network Gateway
S-GW: Serving Gateway
DU
DU
RRU
RRU
Train

Figure 11-38: LTE-R Architecture for High Speed Railway Communication

LTE-R has many differences, such as architecture, system parameters, network layout, services, and QoS. LTE-R will be configured for reliability more than capacity. The network must be able to operate at 500 km/h in complex railway environments. Therefore, quadrature phase-shift keying (QPSK) modulation is preferred, and the packet number of retransmissions must be reduced as much as possible.

11.3.5 Description of LTE-R Services

HSR communications intend to use a well-established/ off-the-shelf system, where some specific needs should be defined at the service level. LTE-R should provide a series of services to improve security, QoS, and efficiency. Compared with the traditional services of GSM-R, some features of LTE-R are described.

- Information transmission of control systems: To enable compatibility with the ETCS or the Chinese Train Control System (CTCS), LTE-R provides real-time information transmission of control information via wireless communications with a <50 -ms delay. While the location information of the train is detected by a Axle counter/ track circuit in ETCS-2/CTCS-3, in ETCS-3/CTCS-4 and LTE-R, the location information of the train is detected by RBC and onboard radio equipment. This improves the accuracy of train tracking and the efficiency of train displacement. LTE-R also can be used to provide information transmission for future automatic driving systems.

- Real-time monitoring: LTE-R provides video monitoring of front-rail track, cabin, and car connector conditions; real-time information monitoring of the rail track conditions (e.g., temperature and flaw detection); video monitoring of railway infrastructures (e.g., bridges and tunnels) to avoid natural disasters; and video monitoring of cross tracks to detect freezing at low temperatures. The monitoring information will be shared with both the Control Center and the high-speed train in real time, with a <300-ms delay. Although some of the aforementioned surveillance can be conducted by wired communications, the wireless-based LTE-R system is more cost effective for deployments and maintenance.
- Train multimedia dispatching: LTE-R provides full dispatching information (including text, data, voice, images, video, etc.) of drivers and yards to the dispatcher and improves dispatching efficiency. It supports rich functionalities, such as voice trunking, dynamic grouping, temporary group call, short messaging, and multimedia messaging.
- Railway emergency communications: When natural disasters, accidents, or other emergencies occur, establishment of immediate communications between accident site and rescue centre is required to provide voice, video, data, and image transmissions. Railway emergency communication systems use the railway private network to ensure rapid deployment and faster response (with a <500-ms delay) compared with GSM-R
- Railway Internet of Things (IoT): LTE-R provides the railway IoT services, such as real-time query and tracking of trains and goods. It helps to enhance transport efficiency and extend service ranges. Moreover, railway IoT could also improve train safety. Most of today’s trains rely on trackside switches located in remote areas. With the IoT and remote monitoring, it is possible to remake trackside infrastructure from switches to power lines, which could automate many of the routine safety checks and reduce the costs of maintenance.

In addition to the features listed previously, some other services of LTE-R should be included, such as dynamic seat reservation, mobile e-ticketing, and wireless interaction of passenger information.

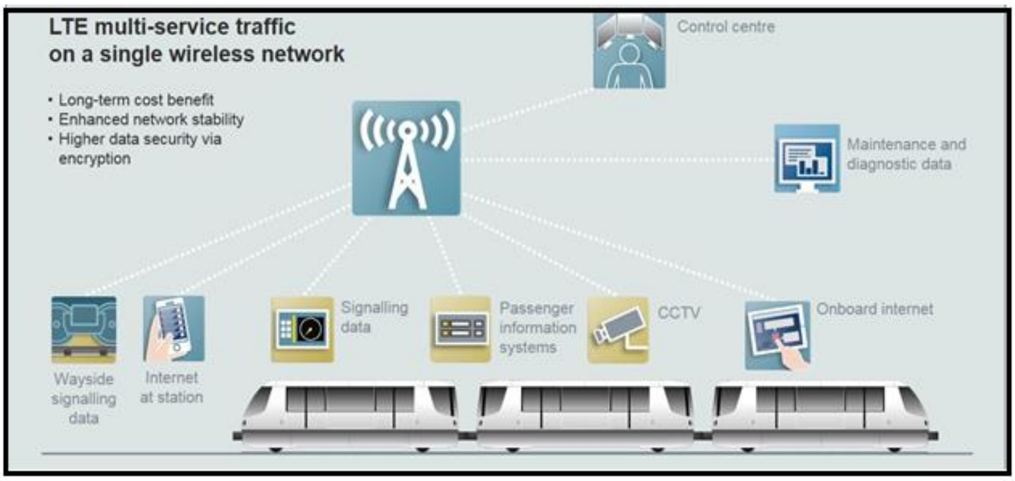
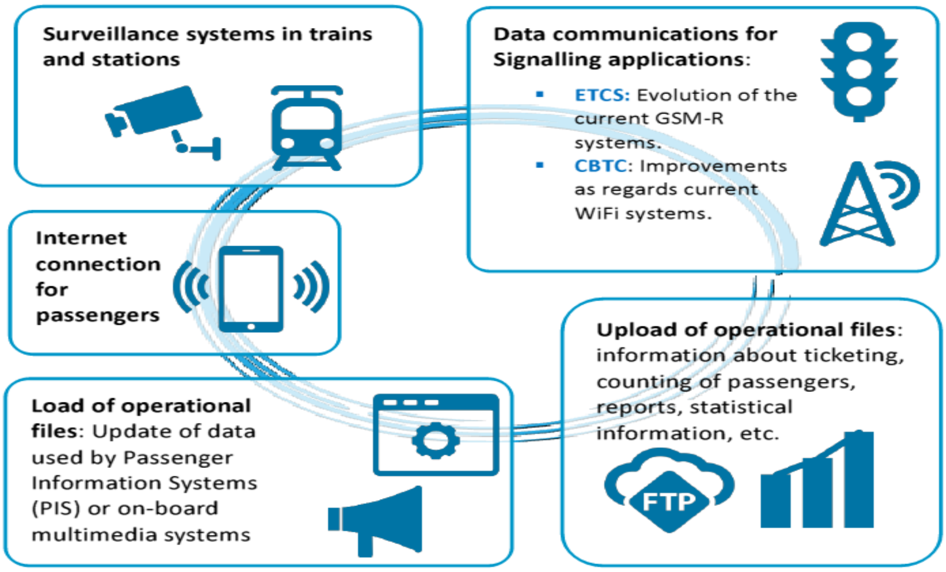

LTE multi-service traffic on a single wireless network
• Long-term cost benefit
• Enhanced network stability
• Higher data security via encryption
Control centre
Maintenance and diagnostic data
Wayside signalling data
Internet at station
Signalling data
Passenger information systems
CCTV
Onboard internet

Figure 11-39 : LTE-R Services for Railway Transportation System

11.3.5.1 LTE Applications for Railway Transportation System:

LTE-R system is dedicated , wireless communications network solution designed to support Voice communication among the drivers, Control Center operators, Maintenance and other railway staff supporting: Push-to Talk group communication, broadcasting, location- dependent addressing and multilevel prioritization: date communication for the train control signalling and other operation and maintenance as well as text messaging during voice communication: multimedia communication for wireless video surveillance, mobile video conference, file sharing, mobile office and passenger infotainment service etc.



Surveillance systems in trains and stations

Data communications for Signalling applications:
- **ETCS:** Evolution of the current GSM-R systems.
- **CBTC**: Improvements as regards current WiFi systems.

Internet connection for passengers

Upload of operational files: information about ticketing, counting of passengers, reports, statistical information, etc.

Load of operational files: Update of data used by Passenger Information Systems (PIS) or on-board multimedia systems

Figure 11-40: Application of LTE-Radio communication solutions

The LTE System features for the following applications are described as below:

11.3.5.2 LTE-R for surveillance system (CCTV)

CCTV systems constitute a key element in the rail safety, helping to reduce the response time in case of incidents, and improving the efficiency in the daily operations, both in the line exploitation and during maintenance tasks. Some of the applicability of these systems are listed below.

Ground surveillance at stations and at critical points along the tracks.	
Mobile surveillance for real-time monitoring from Command & Control Centres, for instance from the train cars.	
Mobile surveillance for real-time monitoring from train cabin of platforms when trains are approaching the station.	

Figure 11-41: LTE-R Surveillance system

Through the LTE system, these applications will be able to transmit and receive video signals from and to the trains and Control Rooms. LTE technology provides an added value to the security and safety in the rail network. To ensure the safety of the passengers is one of the main challenges during the rail operations. Moreover, the protection of workers and the facilities against acts of vandalism, crime and even terrorist attacks, is other of the priorities of the rail operators. Without undermining the functionality of the infrastructure, it must guarantee the mobility of thousands of passengers. Hence, it will be essential to adopt safety measures to protect all the open areas, the accesses to rail infrastructures, point of sales, the trains, etc. In this context, CCTV applications used over professional broadband LTE systems, becomes an essential feature. The broadband radio solutions will provide high availability, QoS mechanisms and the possibility to implement redundancy policies in every single element, and thus being adequate to these kind of surveillance applications.

11.3.5.3 LTE for ETCS rail signalling applications:

ETCS (European Train Control System) is the security and protection system defined within the European rail signalling system ERTMS (European Rail Traffic Management System). It is mainly used in high speed trains or mainlines with the aim to provide interoperability between the rail systems in different countries. This regulation also specifies the wireless communication system for ERTMS, that must be based in GSM-R technology.

ETCS as signalling protocol, provides critical information for the train driving like speed limits, movement authorities, etc., and supervises the train circulation. It can be implemented with different safety levels.

In ETCS Level1, GSM-R system is uniquely used for voice communications. Train-to ground communications take place just at certain cases and through track elements like beacons, circuit systems, etc. In ETCS Level 2, there is a continuous train-to-ground communication over the GSM-R system. Due to the coming obsolescence of GSM-R technology, expected by 2025, Europe is looking into the future and thinking about the next telecommunications system that will support ETCS signalling standard. LTE is now the best positioned technology to play this role.

The ERA (European Railway Agency) has already confirmed several aspects of the next candidate. For instance, future ETCS communications system will be IP-based, as regards GSM-R which is circuit switched. In that sense, LTE is fully aligned with that decision. LTE offers clear advantages with regard to current GSM-R, including an efficient architecture to provide low latencies, and a high data capacity in comparison with the 9.6 kbps provided by GSM-R.

In addition to these features, LTE offers sophisticated quality of service mechanisms (QoS) to guarantee and apply priorities in the reservation of resources for different applications without affecting negatively to the resiliency or the security in the network operation. Moreover, LTE solution for transportation is ready to include key functionalities specific for the professional market which will be implemented and aligned accordingly to the standardization tasks accomplished by 3GPP. Some examples of this functionality are listed next:

- Group calls
- Push-to-talk operation
- Priority and Pre-emption management
- Emergency calls

Significant improvements in the capacity offered by LTE, will allow creating the foundations of a new communication platform that will support any innovation in ETCS systems in aspects related to security, operation and added-value services for passengers.

11.3.5.4 LTE for other applications

LTE can also be the perfect radio interface for other applications that helps to improve the rail operation as well as to enhance security or user services. Next table summarizes some of them

Table 11-13: Examples of other application using LTE technology.

LTE for Other Applications
Updates in the Passenger Information System (PIS): Load of files announcing coming stations. Notification of incidents along the line. Texts in the information panels on board. Texts in the information panels at stations etc.
Update in on board multimedia systems: Load of files for Infotainment systems Load of advertisement files etc.
Download of operational files (from train to control room): Information about ticketing. Information about passenger counting systems. Statistical information about alarms and incidents on-board. Statistical information about the use of the radio network and reports etc.

All of these applications (and others) are not really vital applications, but they help to improve the efficiency and the use of the railway infrastructure, improving the punctuality ratios, resiliency, optimizing the travel times and increasing the line capacity in terms of number of passengers, and thus maximising the benefit during rail operation. To achieve all of these objectives, the availability of the LTE system is essential, enabling a remote and dynamic management of previous applications from the Control Centre.

11.3.6 LTE Device for Operational Voice Communication

The LTE/GSM-R (Mobile Radio Communication system) is used for voice and data communication. The system is based on LTE/GSM -as per EIRENE – MORANE specifications which guarantee performance at speeds up to 350 kmph, without any communication loss.

LTE-R can be used for voice and data communications as well as for traffic control for railways (ETCS, Electronic Train Control System). LTE/GSM-R allows the communication between trains, trackside and railway operation Control Center, the subsystem chosen is LTE-R/GSM-R, the international wireless communications standard for railway communication and applications.

The Radio Block Center (RBC) is a device used at ETCS Level-2 acting as a centralised safety unit which, using radio connection via LTE/ GSM-R, receives train position information and sends movement authorisation and further information required by the train for its movement. The RBC interacts with the interlocking to obtain signalling-related information, route status, etc. It is also able to manage the transmission of selected trackside data and communicate with adjacent RBC's. The most important functionality for RBC on ETCS level-2 is to transmit the movement authority to the onboard unit.

11.3.6.1 Mobile Handset

LTE-R can be used for voice and data communications as well as for traffic control for railway. The mobile handset is used for voice communication by railway staff. Additional railway-specific characteristics include advanced speech call items (ASCI) such as voice group call service (VGCS) and voice broadcast service (VBS) to communicate to a group of handsets simultaneously and facilities are broadcast messages from controllers to certain groups of trains in a controller area

Broadcast messages from trains or shunting team members to controllers or other mobiles in a defined area

Conduct group calls between train drivers and controllers over pre-defined areas

Conduct group calls between trackside workers, shunting team members, station staff and similar groups, typically over local areas.

LTE-R handset are like cellular mobile phones but are more robust. They also offer extended functionality and a different user interface to utilize the additional applications.

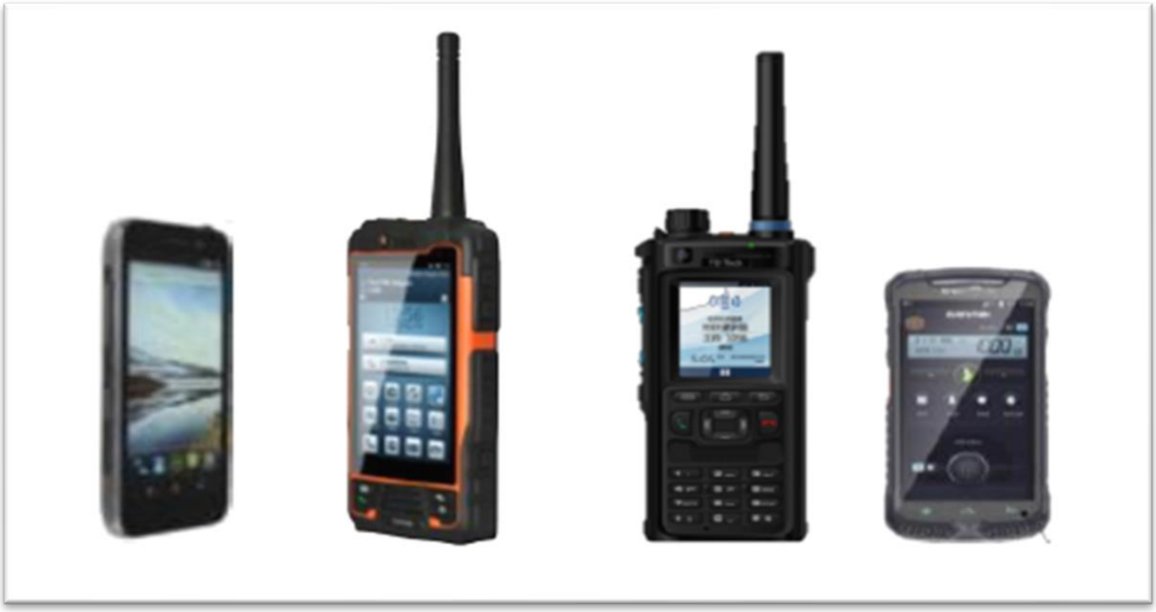


Figure 11-42: Mobile Handset (Sample)

11.3.6.2 Train Borne Radio Set (Communication between Controller and Driver)

The train radio is required for the communication of a train controller with the train drivers and vice versa. There are two major functions of a dedicated type, a voice system and a data system. Voice & data function for traffic control, operational broadcasting, line communication, etc.

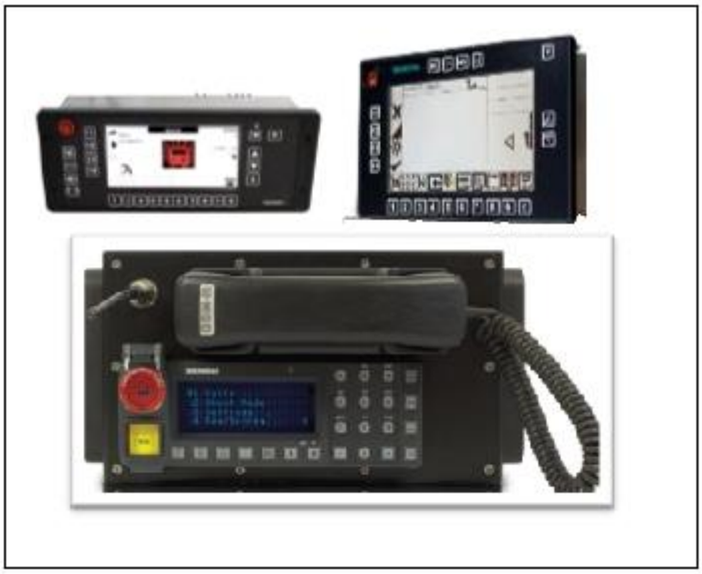


Figure 11-43: Train Borne Radio Set (Sample)

Main function of train radio is to facilitate the communication between train drivers and controller, emergency call, shunting, operational call, depot operation, etc.

11.3.6.3 Dispatcher

The LTE-R Dispatcher subsystem is required for controller at OCC and Depots. The central switching matrix interfaces with all components of the LTE-R. Main dispatcher switch provides interconnection between various communication systems as well as dispatcher terminals. Main dispatcher switch interfaces towards MSC, Voice recording System and dispatcher terminal. In combination with dispatcher terminals the PABX is the basic component to build up a LTE-R System. It supports rail specific features like prioritized calls as well as supplementary services according to EIRENE or latest standard.

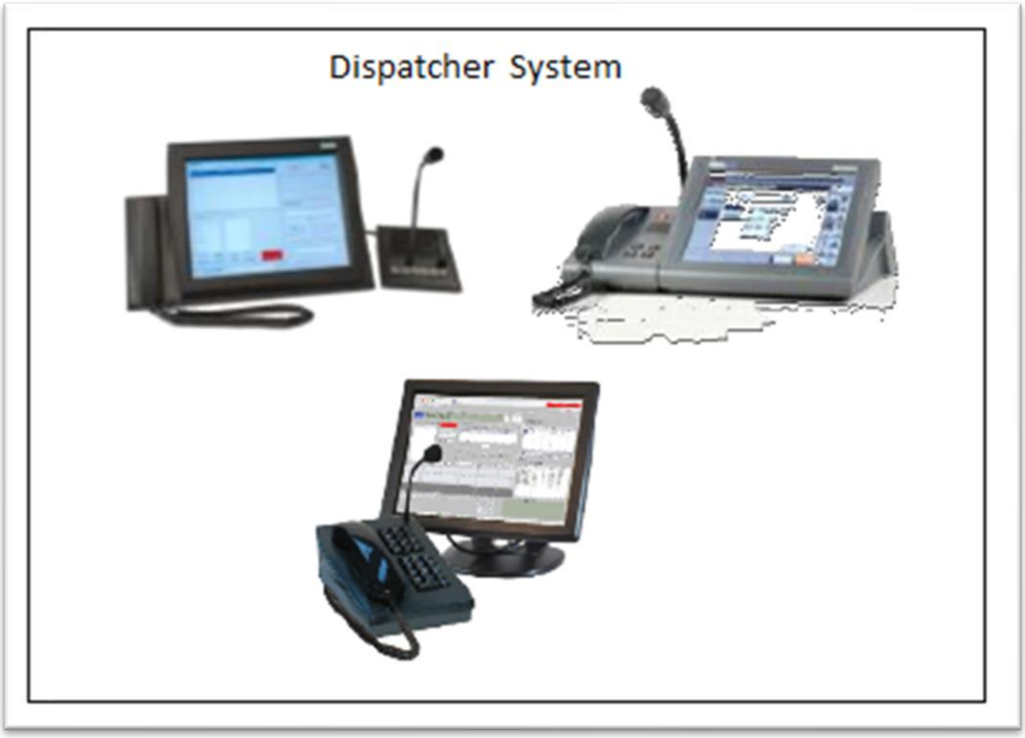


Figure 11-44: Dispatcher Terminal (Sample)

Dispatcher terminal are provided at OCC, Stations, Depot and other important locations of line. Dispatchers at OCC shall have the highest priority to communicate to any stations, depot etc. via the dispatch telephone. The terminal has following functions like calling facilities, Full duplex hands-free operation, Call Forwarding, Waiting, Hold & Queues, Direct Access Keys, Histories, Group call, Broadcast Calls, Conference, Functional Addressing, Call Priority Level, Text Messaging, etc.

11.3.7 Mobile Radio coverage

A fundamental part of the design of a radio network is the radio coverage requirement. For railways, this is mainly driven by the safety and performance requirements of train operations. It is upto individual railways to determine their requirements for coverage levels. For network planning, the coverage level is defined as the field strength at the antenna on the roof of a train (nominally a height of 4m above the track). An isotropic antenna with a gain of 0dBi is assumed. This criterion will be met with a certain probability in the coverage area. (The target coverage power level is dependent on the statistical fluctuations caused by the actual propagation conditions.).

Mainly three types of Antenna adapted by LTE-R are as in Figure 11-45.

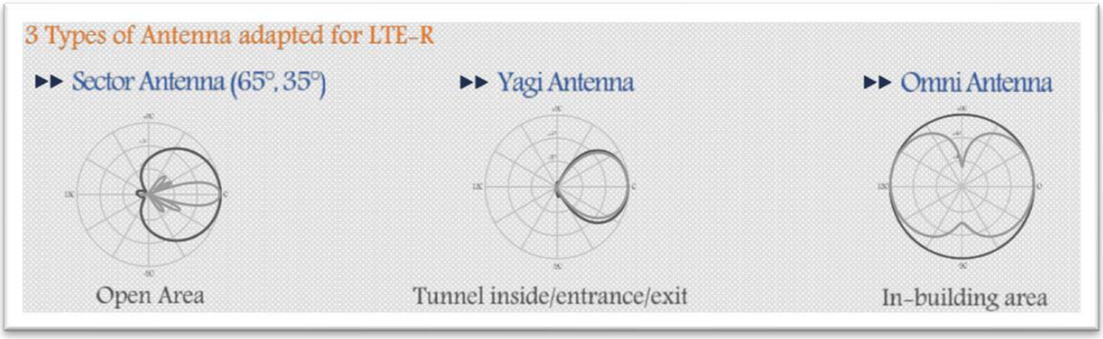

3 Types of Antenna adapted for LTE-R
►► Sector Antenna (65°, 35°)
►► Yagi Antenna
►► Omni Antenna
Open Area
Tunnel inside/entrance/exit
In-building area

Figure 11-45: Type for Antenna adopted by LTE-R System

The following minimum values shall apply (as per UIC guideline): Within a location interval of 100m, the coverage rate should be larger than a probability of 95% with signal strength of -95 dBm.

Table 11-14 : Coverage Acceptance Criteria

Coverage Level	Rx Lev Threshold Output Range (dBm)
Strong Coverage	>-50
Good Coverage	>-95 to -50
Poor Coverage	<= -95

- Coverage probability of 95% based on a coverage level of 38.5 dB V/m (-98 dBm) for voice and non-safety critical data.
- Coverage probability of 95% based on a coverage level of 41.5 dB V/m (-95 dBm) on lines with ETCS levels 2 for speeds lower than or equal to 220km/hr.

The specified coverage probability means that with a probability value of at least 95% in each location interval (length: 100m) the measured coverage level shall be greater than or equal to the figures stated above. The coverage levels specified above consider a maximum loss of 3 dB between antenna and receiver and an additional margin of 3 dB for other factors such as ageing. The values for ETCS levels-2 concerning coverage and speed-limitations are to be validated and, if necessary, reviewed after the first operational implementation of ETCS.

In order to understand the meaning of these guidelines, it should be appreciated that due to various conditions, the signal strength at any particular point on the network will vary as a function of time. This aspect and the availability of the network need to be factored into any coverage level calculations.

Finally, it is not sufficient to provide coverage requirements as outlined above. In addition, the railway must guarantee that coverage levels are actually maintained at the right level over time. This requires performance measures and an associated performance monitoring strategy to be defined.

11.3.8 LTE-R Network Structure

Since the integrated wireless network for Railway delivers the important data related to the safety of the train operation (including the train position, train operation control, and train status monitoring), wireless communication network should have much higher availability than that of common commercial network. Thus, by duplicating wired network equipment as well as wireless coverage, as shown in below figure, train terminals always have the hot standby function. In other words, the end terminal can receive the data from two base stations at the same time. The network should be designed to avoid any interference with failures of a certain network/ eNodeB.

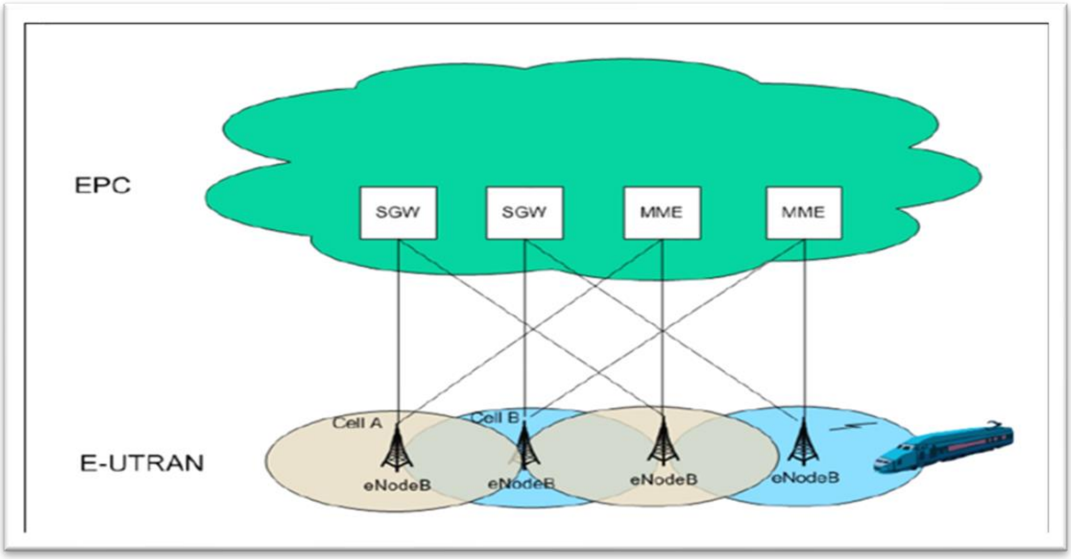


Figure 11-46: Fully duplicated network with overlaid radio cell coverage for LTE-R

Handover eNodeB to eNodeB: For the definition of the handover range it must be possible to receive the two cells without interference for 8 seconds. At a speed of 200 kmph this works out at a distance of 450 metres. Another important consideration in the planning of the radio network is that it is necessary to ensure that within the range of registration balises or any MA balise devices, LTE-R is not directly in a handover state before and after the balise.

The diagram above shows the planning strategy for assuring the provision of redundancy. The following preconditions exist for the dimensioning of cells where balises are located in the supply perimeter:

- Average coverage of a cell in the event of redundancy: approx. 3000m – 4000m

It is assumed that approx. 4s is required at the cell boundaries so that the system returns to a stable condition after the handover. At 200 kmph this means that the balises should be no more than approx. 1300m away from the antenna.

As per Railway applications requiring high degree of reliability will mandate use of the multidrop loop LTE-R architecture. The Radio coverage shall not be provided less than 98% on track line (with tunnel area). The network structure design is prepared by taking minimum 250 kmph speed into account for successful handover. This fully duplicated network with overlaid radio cell architecture is proposed for Silver-Line project.

11.3.9 Radio Coverage in Tunnels

Tunnel provision of radio coverage for cellular application requires special attention. Directional/high gain antennas may be used to direct a radio signal into a tunnel portal; however, the actual propagation inside the tunnel bore is limited. Under a pure railway application, it is usually possible to gain access to the portal superstructure itself, thus eliminating dominant diffraction mechanisms with respect to signal entry, but in many cases, this may be untenable due to catenary apparatus or other installations/physical (or other) restrictions.

Installation of rack mounted radiating cable is often a more suitable solution, particularly for longer tunnels or sites where access to the tunnel portals is limited. Radio coverage from radiating cables is highly reliable and the required signal levels can easily be calculated and realized. Loss per given length of the cable is easily measured as is that for train signal penetration. Transmission loss between cable and train is very small and due to the distances involved there is little opportunity for Rician fading to manifest.

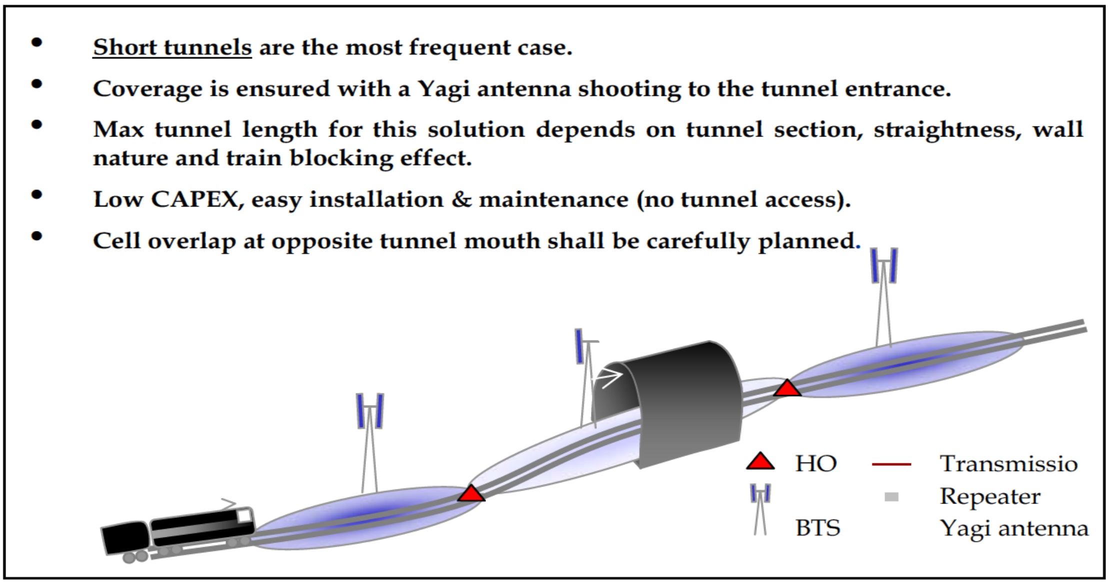
It is normal for coverage in tunnels to be provided to 200%, thus implementing 100% redundancy, across the radio element. The RAM metrics of radiating cable generally do not indicate the requirement of redundant cable installations or runs. Environmental conditions may impact this and should always be individually evaluated.

The technical solutions used today are:

- eNodeB/Base Stations with directional antennas into the tunnel,
- eNodeB/Base Stations with radiating cable inside the tunnel and handover antennas at the entrances

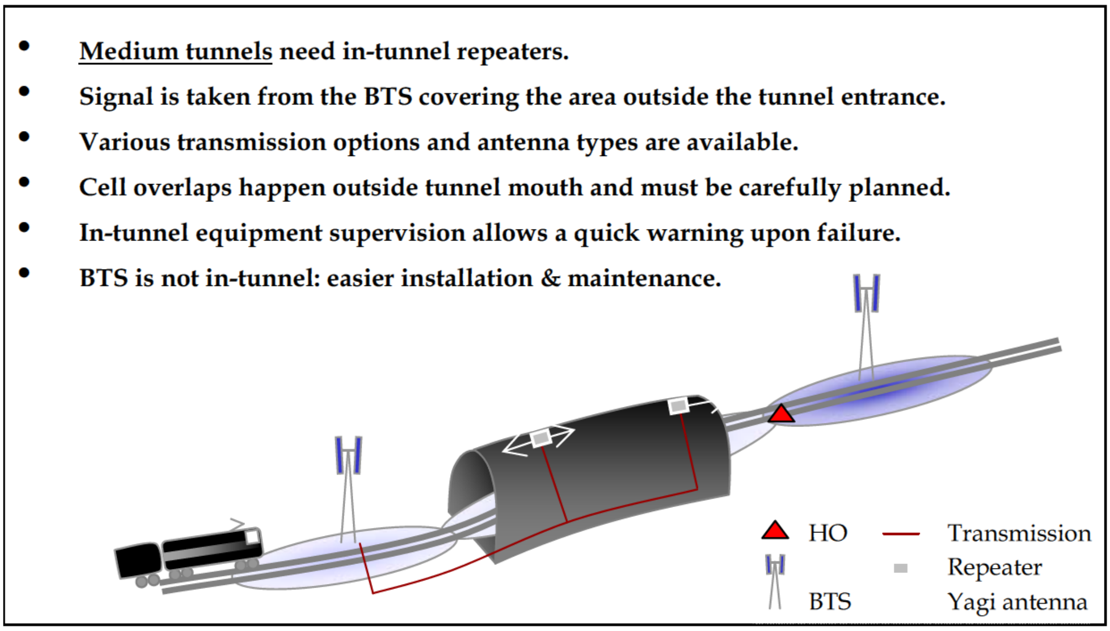
- RF –feeded (feeded via the air) repeaters
- RF-feeded, frequency converting repeaters

Here below, are general considerations on tunnel radio coverage for technical solution used presently are:



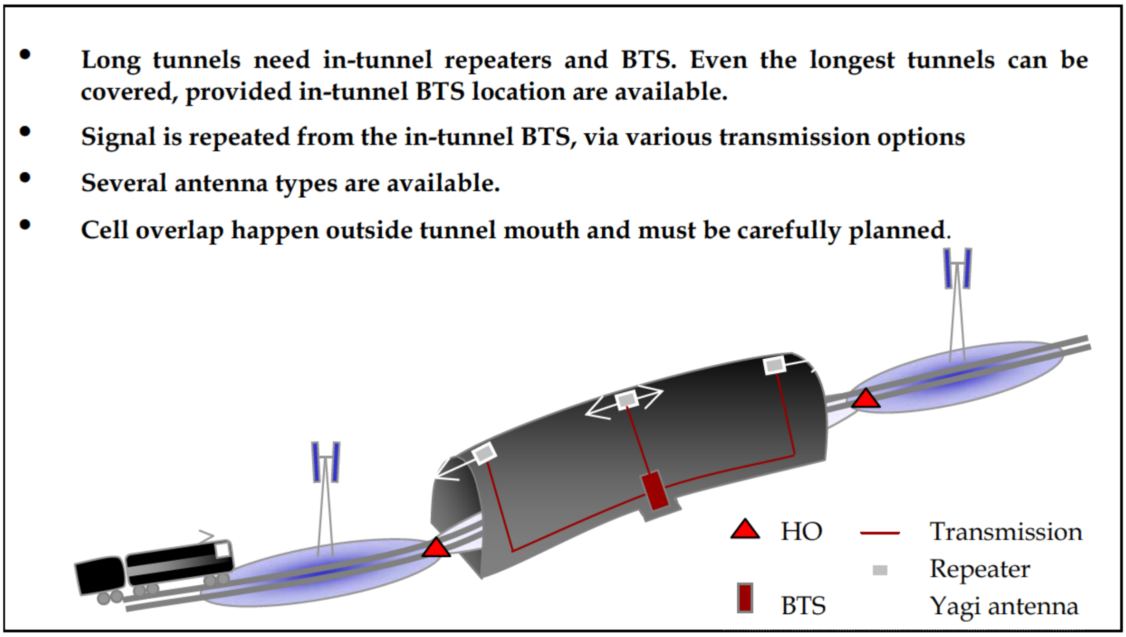
- **Short tunnels are the most frequent case.**
- **Coverage is ensured with a Yagi antenna shooting to the tunnel entrance.**
- **Max tunnel length for this solution depends on tunnel section, straightness, wall nature and train blocking effect.**
- **Low CAPEX, easy installation & maintenance (no tunnel access).**
- **Cell overlap at opposite tunnel mouth shall be carefully planned.**

Figure 11-47 : Radio Coverage Solution for short tunnels



- **Medium tunnels need in-tunnel repeaters.**
- **Signal is taken from the BTS covering the area outside the tunnel entrance.**
- **Various transmission options and antenna types are available.**
- **Cell overlaps happen outside tunnel mouth and must be carefully planned.**
- **In-tunnel equipment supervision allows a quick warning upon failure.**
- **BTS is not in-tunnel: easier installation & maintenance.**

Figure 11-48: Radio Coverage Solution for medium tunnels



- Long tunnels need in-tunnel repeaters and BTS. Even the longest tunnels can be covered, provided in-tunnel BTS location are available.
- Signal is repeated from the in-tunnel BTS, via various transmission options
- Several antenna types are available.
- Cell overlap happen outside tunnel mouth and must be carefully planned.

Figure 11-49 : Radio Coverage Solution for long tunnels

Other technical solution for tunnel communication through leaky coaxial Cable. A leaky cable will be mounted in the tunnel. Distributed repeater in combination of Master Unit (MU) and Remote unit (RU) shall be used. Master Unit is connected with Base Terminal Station (BTS).

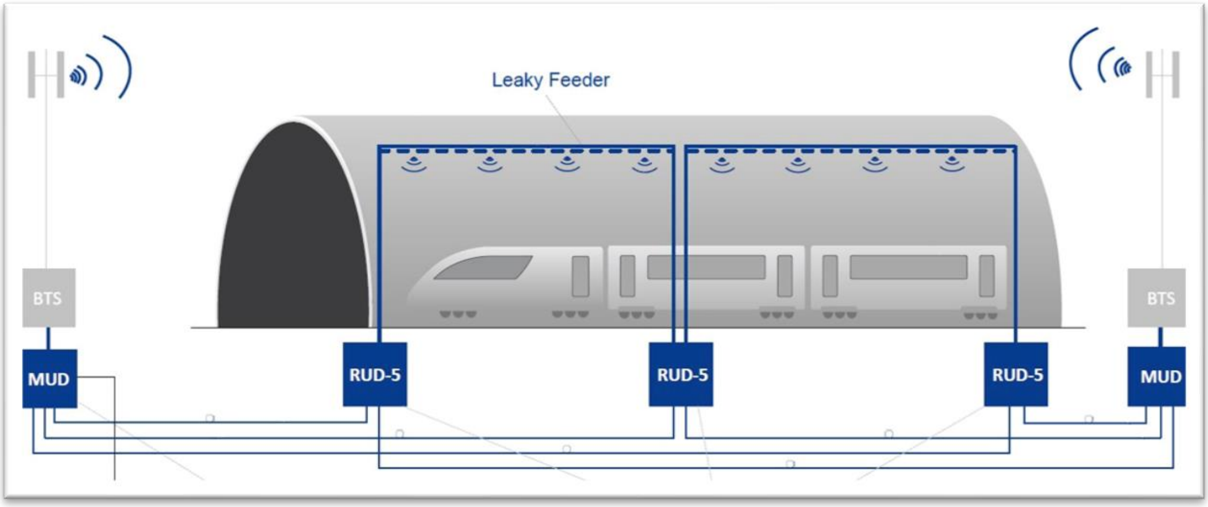


Figure 11-50: Radio coverage with Leaky Coaxial Cable

11.3.10 Communication System Network

The communication system shall be designed to allow operators to manage with a high level of efficiency normal train operation and maintenance works. A specific attention shall be provided to the communication means required to manage efficiently and safely degraded and emergency situations.

The Communication System provides the medium for the delivery of voice and data signals throughout the High-Speed Rail Line. The High-Speed rail line are usually controlled from Operational Control Center (OCC) and Communication system shall fit the needs of the operators in the OCC especially:

- The chief controller- who need to liaise with large numbers of railway stakeholders including emergency service providers and the emergency management room.
- The traffic controller(s) (signallers), responsible for managing the traffic operation who needs to liaise with train crew, station and maintenance staff.
- The power controller(s), responsible of controlling the power supply equipment, who needs to liaise with local power suppliers, maintenance staff as well as emergency service providers.

The staff responsible for the supervision of the HSL technical equipment, who needs to liaise with the maintenance staff as well as with the operators. The staff responsible for service like -passenger information (PAS/PIDS), safety and security, CCTV, building security (access control, fire detection, etc.), interface with the crew office & train crew and liaise with staff for other services of HSR line.

The Communication system acts as backbone for all systems of High-speed rail network. The system shall be provided communication service to meet operational & administrative requirement of High-Speed Rail corridor. For operational safety and to reduce the number of failures, systems that are critical to the HSR operations shall adopt redundant design, so as to prevent interruption of communications and thus affecting the train safety and revenue service.

The main functions of a Communication system are to provide:

- Voice communication for Operation, Administrative, Maintenance, Security staff and for other services of rail network.
- Data transmission for Signalling, Communication, Ticketing & Fare Collection System (Ticketing and Booking), Power supply, SCADA, Security & Safety and other systems of Rail network.

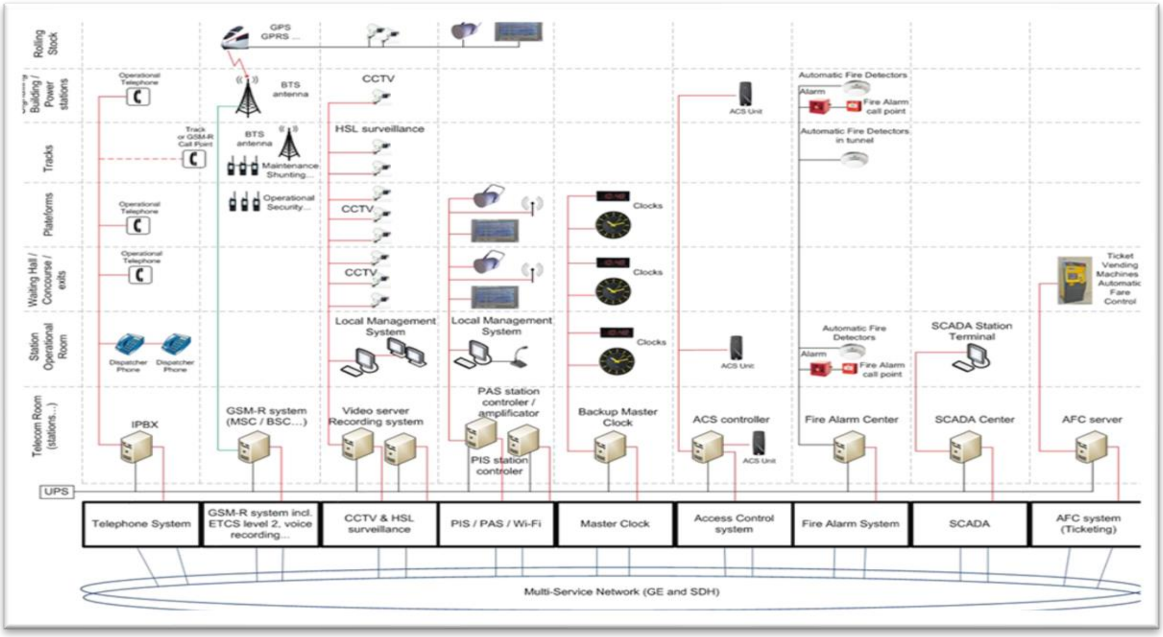


Figure 11-51: Communication System Network Architecture

The reliable Digital Train Radio system and fiber optic-based data transmission backbone should be considered for safe and reliable operation of High-Speed Rail Line. A data transmission network shall be provided to serve the OCC, back-up OCC, maintenance base offices, stations, tunnels depots and other line side locations. The network shall be expandable in capacity to accommodate the future possibilities.

11.3.11 Backbone Transmission Network (BTN) using OFC

Fibre optic transmission is widely used for data transmission and is increasingly being used in place of metal wires because of its efficiency and high transmission capacity. The heart of the Communication System is a fibre optic-based data transmission backbone that shall be capable of reliably handling all communication traffic on the High-Speed rail Line.

Optical fibres have largely replaced copper wire communications in core networks in the developed world, because of its advantages over electrical transmission. Here are the main advantages of fibre optic transmission.

- Extremely High Bandwidth: No other cable-based data transmission medium offers the bandwidth that fibre does. The volume of data that fibre optic cables transmit per unit time is far greater than copper cables.
- Longer Distance: in fibre optic transmission, optical cables are capable of providing low power loss, which enables signals that can be transmitted to a longer distance than copper cables.

- Resistance to Electromagnetic Interference: in practical cable deployment, it’s inevitable to meet environments like power substations, heating, ventilating and other industrial sources of interference. However, fibre has a very low rate of bit error (10 EXP-13), as a result of fibre being so resistant to electromagnetic interference. Fibre optic transmission is virtually noise free.
- Low Security Risk: the growth of the fibre optic communication market is mainly driven by increasing awareness about data security concerns and use of the alternative raw material. Data or signals are transmitted via light in fibre optic transmission. Therefore, there is no way to detect the data being transmitted by "listening in" to the electromagnetic energy "leaking" through the cable, which ensures the absolute security of information.
- Easy to Accommodate Increasing Bandwidth: with the use of fibre optic cable, new equipment can be added to existing cable infrastructure

Usually, a fibre optic communication system consists of three main components: optical transmitter, fibre optic cable and an optical receiver. The optical transmitter converts electrical signal to optical signal. The fibre optic cable carries the optical signal from the optical transmitter to the optical receiver and the optical receiver reconverts the optical signal to electrical signal. The most commonly used optical transmitter is semiconductor devices like LEDs (light-emitting diodes) and laser diodes. Photodetector is the key part of an optical receiver. It converts light into electricity using photodetector effect. As for the fibre optic cable, there is too much to say. The use and demand for speed and bandwidth, the development of optical cables is amazing. It is especially advantageous for long-distance communications, because light propagates through the fibre with little attenuation compared to electrical copper cables. The figure below shows that all fibre optic transmission systems use modulated light to convey information from a transmitter to a companion receiver.

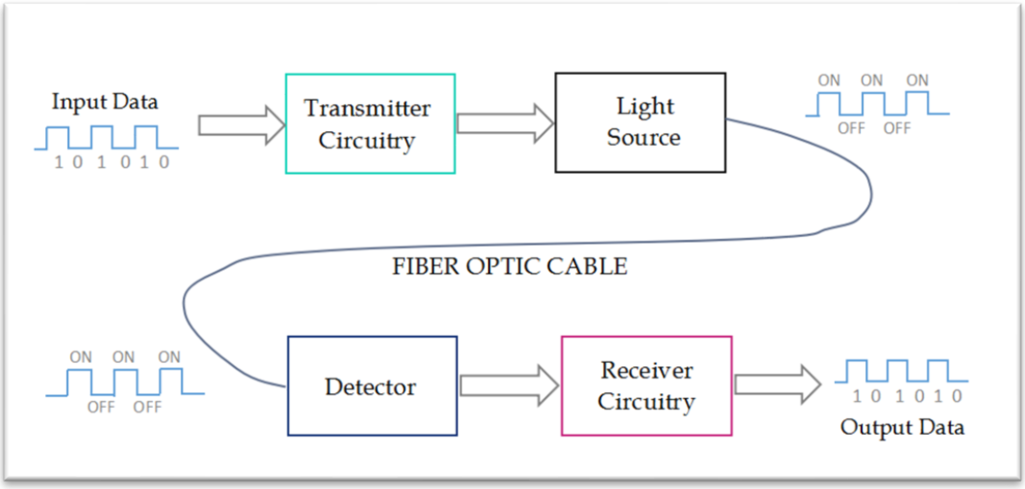


Figure 11-52 : Illustration of a basic fibre optic transmission system

Backbone Transmission Network (by OFC) to give end to end communication connection between distant places and to provide connectivity through every site location along the section will be provided. The optical fibre shall provide enough transmission bandwidth to cater to all operational requirements of this rail line network and spare for future expansion of system requirement.

The OFC cable serves all the installations having to receive communications equipment, such as the signalling stations, power supply & SCADA system, sub-stations, stations, depots, maintenance buildings, line side locations, tunnel as well as the track-to-train radio cabins. This cable connects these various points of the network of the High-Speed Rail Line (HSRL) to the OCC equipment.

The optical fibre cable shall provide common transmission backbone network for Telecom, Signalling, Power, SCADA and other systems which are formed by the two outdoor single mode optical fibre cables. The OFC cable shall be laid on both side of track with full redundancy for all system requirement. A minimum 144 fibre optical cable with full redundancy shall be provided for backbone transmission network for all the systems. All the cable laid in tunnels and stations are of low- smoke zero halogen type. Additional fibre optical cable shall be laid along the track for commercial requirements for revenue.

11.3.11.1 Synchronous Digital Hierarchy (SDH) network

SDH is a standard technology for synchronous data transmission on optical media. It utilizes light-emitting diodes (LED) or lasers for synchronous optical fiber communication. SDH can improve network reliability and performance, offers much greater flexibility and lower operating and maintenance costs. The SDH equipment provides the flexibility of configuration to Terminal, Add Drop Multiplexer, Regenerator and Cross Connect. By using the protection mechanisms of SDH network as well as the Network Management functionalities, a redundant 1-ring structure is implemented to assure the continuity of all communications in case of any possible fibre cable failure by automatically re-routing traffic over the alternative paths.

The SDH Equipment shall support “Ethernet Over SDH” (EOS) transport capability at Fast Ethernet Interface and Optical Gigabit Ethernet Interfaces. IP network shall have important data like transmission of train control signals therefore the network requires high reliability.

Main communication network provides a highly reliable multiple single path in 4-fiber Multiplex Section Shared Protection Ring (MS-SPR) topology with STM-16/64 covering signal equipment rooms in Stations, Depots and OCC. The 4-fiber MS-SPR topology can be used up to 100% for protection channel or for extra traffic, support ring switch and span switch.

This SDH network consists of STM-64 as main communication network and SDH (minimum STM 16/64) based system will be adopted with SDH nodes at every Station, Depot, OCC and line side location. A Network Management System (NMS) shall be installed at OCC. The network shall be synchronized with master clock system.

11.3.11.2 Gigabit Ethernet Network (GbEN)

To support relatively less important facilities for the rail operation viz. CCTV, Ticketing system, Maintenance management system and PA, Clock, PIDS, Telephone System, SCADA etc., a Gigabit Ethernet network shall be used. Redundant Layer-3 switch at each Station, Depot OCC shall be provided. This network shall use the same OFC as the SDH network. The network is supposed to be 10 Gigabit Ethernet network. The communications network shall be configured as LAN and WAN. LAN shall be responsible for train operations and maintenance tasks within each passenger station and WAN shall be responsible for mutual communications between the stations and between depot and the central computer system. To maximize the reliability and survivability, each equipment and each transmission line are configured as a dual system.

11.3.12 Telephone System

The telephone system provides voice, fax, email, video and data communication between railway personnel both internally and external for train operation management. Railways require telephone system for train operation, control, maintenance and administration. Telephone system will consist of IP PBX exchange (Internet Protocol Private Branch), Dispatcher telephone, Emergency Telephone, IP Phone (Voice & Video) etc. Help points also provides for passengers for assistance inside the stations. The Telephone System shall consist of the following subsystems:

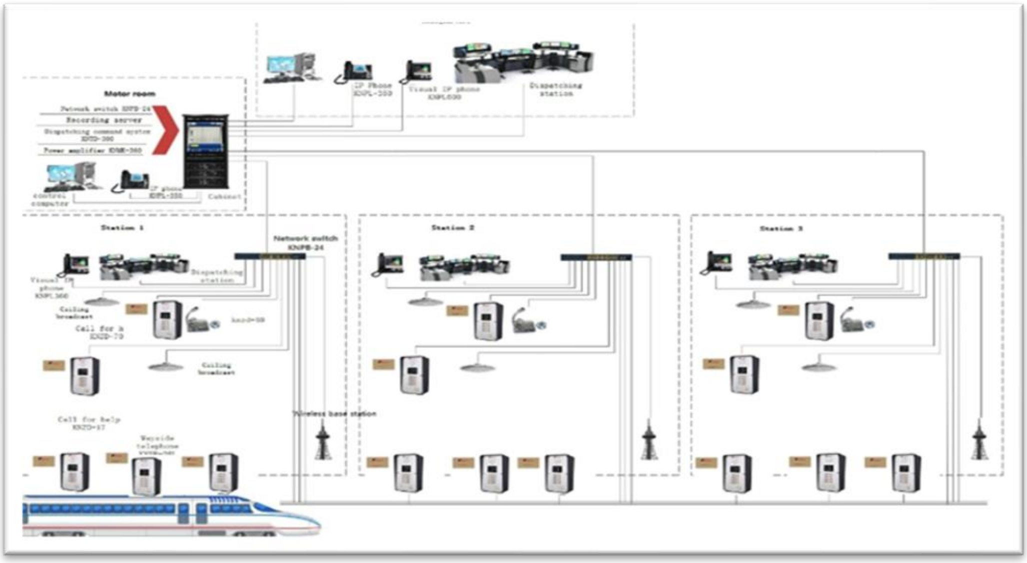


Figure 11-53: Overview of Telephone System

11.3.12.1 IP PBX telephone exchange

An Automatic Telephone system shall be provided and shall comprise an automatic exchange system that enables communications between dial telephones located throughout the High-Speed Rail Line (HSRL). This Operation Telephone system shall allow voice/videos communications between operation and maintenance staff (i.e. OCC staff, station staff, crew offices, depots and maintenance bases staff) and should allow connection to the track-to-train radio system.

The IP PBX is highly reliable state of art, non-blocking, ISDN compatible IP PBX telephone network for Voice, facsimile and data communication service throughout the rail corridor. IP PBX network equipped with IP PBX switch, line and trunk interface units and different types of telephone sets for communication. It also interfaces to radio system to enable radio user to initiate and receive call from IP PBX extension or from PSTN telephone.

Unified Messaging Application: This is provided for IP PBX system with facilities such as Email, Voice mail, Faxes, Conferencing & Collaboration and inbuilt Soft phone. The Unified Messaging Application is accessible from desktop clients and supports features such as making calls, sending, replying, forwarding Voice messages and recording live conversation and accessing the IP PBX services. UMA supports Unified directory that allows the IP Phone, Soft phone user to call by name and identify their correspondents. A Conferencing and Collaboration application is also provided for all types of IP Phones (soft phones included) under UMA for Audio Conferencing, Data collaboration & Video Conferencing.

IP PBX at stations shall be connected in a ring topology (group of stations) with IP PBX at OCC. Each group of stations shall be connected to the main node of OCC directly on Ethernet link in redundant configuration. IP PBX network also interface with Public addressing System to broadcast message & announcement to station and other strategic location. The main IP PBX system shall be installed at OCC and redundant at back-up OCC (redundant configuration).

11.3.12.2 Dispatch telephone system

Dispatcher system is provided at OCC. The Dispatch telephone system shall be provided at each Station, Depot, Workshop, Maintenance depot, Substation, Signal & Telecommunication equipment room and other line side location for communication. An integrated communication console will be provided at OCC. Dispatchers at OCC shall have the highest priority to communicate to any stations, etc. The system shall ensure instant, uninterruptible, communication between key points.

11.3.12.3 Voice Over IP Phones System

The Voice Over IP telephone communication system provides telephone lines over IP network using proven protocols such as H.323, SIP etc. for Stations, Depot and OCC.

The system ensures instant, uninterruptible, real time audio/video communication between key points. OCC system shall have highest priority to communication to any station or line side location.

11.3.12.4 Emergency Telephone system

The system shall provide a highly reliable and high availability telephone communications as a means of reporting and aiding a response to emergency situations that may arise in tunnels. The system shall be simple in operation to allow use of telephones by untrained staff, emergency services staff and anyone from the general public that may be caught up in an emergency in a tunnel. The wayside telephone shall be interconnected by Backbone system (OFC) on IP PBX exchange system.

The Emergency telephone shall be installed at following locations:

- Wayside telephone sets shall be installed at every 500m (approx.) interval in underground and tunnel section.
- Wayside telephone sets shall be installed at every 3000m (approx.) of interval in open section such as embankment and viaduct.
- Emergency telephone shall be installed at each station platforms and passenger area.
- Emergency telephone shall be installed at depot, substation & other way side locations.

11.3.13 Centralised Digital Recording System (CDRS)

A centralized digital Recording System (CDRS) shall be provided at OCC with enough recording capacity for minimum 30 days for continuous operation like Radio, Telephone, PAS/PIDS, etc. The CDRS shall record all telephone conversations of all dispatchers at OCC and at Stations. The Telephone System shall be interfaced with a Centralised Digital Recording System for recording of designated telephone lines including emergency telephone lines.

Radio conversation shall be recorded by CRDS located at OCC. Also, emergency announcement on Train borne PA system initiated from Radio console at OCC shall also be recorded. The voice recorder shall be located securely in the OCC and shall only be accessible to senior Operations Management staff to prevent tampering. The recording medium shall also permit erasing and re-recording as per guideline of government and comply with a Relevant Standard as applicable.

11.3.14 Passenger Information Display System (PIDS)

The passenger information system is based on the multimedia and network technology. The system is installed in the OCC, Station and Depots, wherein the display terminal will display multimedia information to passengers. PIDS information shall be dynamic and continuously updated based on the actual location of trains from the signalling system at OCC. The PIDS shall display train information like:

- Schedule of train arrivals and departures
- Platform of each train information
- Stoppage and delay time of trains
- Welcome, General and Service message
- Date & time information

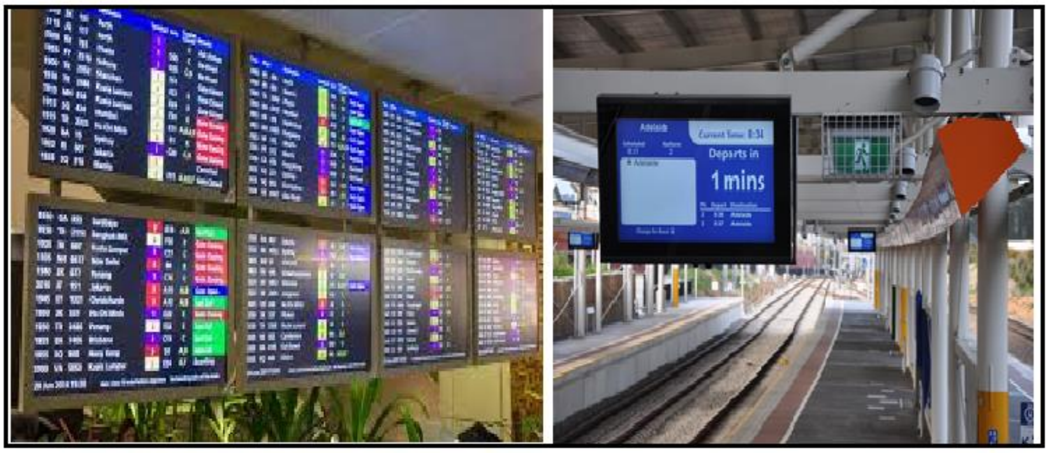


Figure 11-54: Sample of PIDS at Station area & Platform

The passengers will timely and accurately know the train operation information and public announcement information. Under normal circumstances, the PIDS system provides train travel time information and advertising etc.

In emergency events (such as fire) the PIDS system is used to provide the emergency evacuation messages and system shall comply with the local rule and regulations as applicable. The equipment of passenger information system will be deployed in the OCC and stations. The backbone transmission network shall be used for data transportation from Station/ Depot to OCC and vice versa. OCC subsystem is mainly responsible for the system configuration, media edit, layout edit, equipment status monitoring, preview broadcast effect, interfaces and network management.

11.3.15 Passenger Address System (PAS)

Public Address System (PAS) provides broadcasting of voice messages to passengers / staff in all Stations, Depots, Tunnel and OCC. It can also be used for emergency evacuation broadcast in case of emergencies. It includes speaker and amplifier linked to the station. The Public Address System (PAS) and Passenger Information Display System (PIDS) shall be coordinated automatically to provide real time passenger audio broadcast and visual information at each station. The PAS/PIDS system shall be linked to signalling system for automatic train actuated announcements. The system should be able to support several types of message:

- Live announcements from a local controller / from the Control Centre (OCC)
- Pre- recording messages from local controller or from Control Centre (OCC)
- Variable messages composed of pre-recorded elements with a fixed and variable element (train number, time, destination, scheduled stops).

It will have capability for different Live or Recorded announcements to separate Zones or Group of Zones simultaneously within a station. In addition to announcements from Designated Hand Portable Radios to a set of pre-defined Zones at each station.

The OCC is the global control Centre for the PIDS/PAS system. From the OCC system wide control of Station Control Rooms (SCRs) is possible. The SCR is the local PIDS/PAS installation exists in each station. It manages the local PIDS/PAS system of that station. In case of audio broadcasting relating to emergency, fire and evacuation messages from OCC and Station Control Room shall be recorded in the Centralised digital recording system at OCC. The backbone transmission network shall be used for data transportation from Station/ Depot to OCC vice versa.

In case of emergency, security reasons, fire etc., priority will be given to such safety announcements (pre-recorded message or voice messages) and system shall comply with the local rule and regulations as applicable.

11.3.16 Time Distribution System (TDS)

Time Distribution system is to provide exact and reliable time information throughout the rail infrastructure in the form of analog and digital clocks in addition to time information for electronic system. The Time Distribution System (TDS) consists of primary Master Clock located at OCC, one secondary Master Clock located at BCC and Slave Clocks including Analog and Digital Clocks in Stations and Depot.

The Time Distribution System (TDS) mainly includes three equipment which meets total functional requirements as:

- Primary Master Clock
- Secondary Master Clock
- Analog and Digital Clocks

Time reference, usually a GPS-time-signal receiver, will be provided to correct the time deviations of the Master clock timeserver. These time deviations are mainly caused by frequency drifts and aging of the internal quartz-oscillator of the Master clock. Master clock timeserver generates the time-/date- information for the slave clocks and computer-controlled systems such as CCTV, PIDS, PA System, GSM-R, Signalling, Power Supply, SCADA, Telephone system, Safety & Security system and other systems of HSR corridor.

11.3.17 Closed Circuit Television System (CCTV)

CCTV system is based on the latest network video technologies, making use of sophisticated computer-controlled systems with artificial intelligence through cameras to ensure effective surveillance of an area as well as to create temper proof video recording for post event analysis. CCTV system shall be provided for real-time and visual supervision through the wall displays, selecting specific location or all the public area in stations as well as in OCC. The CCTV system can also equip with monitoring and zooming of terrorist and mischievous activities by suitably incorporating the artificial intelligence and data analytics software. The CCTV system should be installed at following minimum locations:

- Stations, Depots and line side locations
- OCC & Administrative building
- Stabling & parking area
- Main line & Depot entry and exit area
- Tunnel, Radio tower location, Underpass and bridge etc.
- Other important location on Viaduct etc.

The CCTV system shall be based on the latest network video technologies, making use of sophisticated controlled system through cameras (like -Fixed , Remote, PTZ etc. cameras (HD-IP), Passenger monitoring with decoders, Network switches, Network Video Recorders, Local & Central Server and Video Investigator application & Management software (Latest). Each location system should be connected to central server located at OCC via backbone transmission Network. The CCTV server and other main sub-system shall be redundant in configuration.

The CCTV system both live and recorded videos shall be accessed simultaneously from the following location as minimum:

- OCC and BCC Controllers
- Station & Depot Control Room
- Security Room at OCC, Station & Depot

It will also provide the integration of CCTV with Access Control of important room, sensitive sites & line side locations (such as administrative offices, Control room, OCC building, each technical building of signalling, telecommunications, power, substation, maintenance and other technical locations). The Access Control system shall allow the management of individual accesses, by profile or mixed with a choice of technologies (smart card, biometrics, vehicle plate's recognition) and shall detect intrusion of all remote and / or sensitive sites through motion detectors.

CCTV monitor will be provided for displaying real-time pictures of each camera and recording playback. The surveillance system shall be provided at Stations, Depot and OCC for monitoring and CCTV recorder shall be located securely in a technical room (OCC, BCC, Central Security Center) and shall only be accessible to allowed staff to prevent tampering.

The recorder shall permit playback / investigation whilst the live stream is kept recording. The recording medium shall have an absolute minimum recording capacity of 30 days. The recording medium shall also permit erasing and re-recording, comply with a Relevant Standard and local Rule and Regulations as applicable.

11.3.18 Adoptable Standard Specifications

The most important standards to be applied for Communication systems are:

- EN 50126 (Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS))
- EN 50128 (Railway Applications - Communication, Signalling and Processing Systems - Software for Railway Control and Protection)
- EN 50129 (Railways applications – Communications, signalling and processing systems – safety related electronic systems for signalling)
- EN 50159 for Railway Applications - Communication, Signalling and Processing Systems

These define the RAMS (Reliability, Availability, Maintainability and Safety) and requirements for designing the safety critical system. The other standards to be applied for communication system are:

- EN 301 515 for requirements for GSM operation on railways
- TS 102 610 for usage of the User to User Information Element
- TS 102 281 for detailed requirements for GSM operation on Railways
- EN 50122 for Railways Applications Fixed Installations - Electrical Safety, Earthing and the Return Circuit
- EN 50121 for Electromagnetic Compatibility
- EN 50125 for Railway Applications - Environmental Conditions for equipment
- EN 50155 for Railway Applications - Electronic Equipment Used on Rolling Stock
- EN50153 for Railway applications - Rolling stock - Protective provisions relating to electrical

- EN 50238 for Railway applications – Compatibility between RS and train detection systems
- EN 50261 for Railway Applications - Mounting of Electronic Equipment. General Product Information
- EN 55264 for Railways fixed equipment – telecom wires for underground networks
- EN 302608 for Electromagnetic compatibility & spectrum (ERM) – Eurobalises
- TS 22.280 for Mission Critical Services Common Requirements (MCCRe)
- TS 22.179 for Mission Critical Push to Talk (MCPTT) Stage 1
- TS 22.281 for Mission Critical Video services
- TS 22.282 for Mission Critical Data services
- TR 22.889 for Study on Future Railway Mobile Communication System
- TR 103.459 for FRMCS System architecture
- TS 22.289 for Future Railway Mobile Communication System (FRMCS)
- UIC Specification version 4.0.0.(latest) FRMCE user requirements specification

All safety critical equipment shall be designed to conform to fail- safe principles in respect of RAMS, manufactured/OEM, validated to meet the safety Integrity level, in compliance with relevant latest version of international standards like British Standards ,European Standards (EN), Indian Railway Standards (IRS), international Electromechanical Commission (IEC) standards, 3rd Generation Partnership Project (3GPP), International organization for Specification (ISO) standards, International Union of Railways (UIC) and other international standards that are widely accepted for HSR.

The transmission media and equipment needs to be in redundant configuration so that a single failure does not cause a hazardous failure. The system delays need to be taken into account. The more equipment and transmission required for movement authority, the more probable it is to have system delays and errors. Hence, there is an increased risk of having problems in train traffic caused by Signalling & Communication systems, which needs to be considered in the system design phase. These delays also affect the safety of the railway system, when the train should be stopped in case of emergency.

The design of communication and its Operation & Maintenance shall, in general, comply with recommendation of NFPA 130 (Standards for fixed Guide Way-Transit and Passenger Rail System). This standard specifies fire protection and life safety requirements for underground, surface, and elevated fixed guideway transit and passenger rail systems.

11.3.19 Facility -Supervisory Control and Data Acquisition (F-SCADA)

F-SCADA (Supervisory Control and Data Acquisition) can realize that dispatchers in OCC confirms and monitor conditions of equipment and data on measurers for disaster information, so they can precisely instruct train crews and maintenance staffs and control train operations to prevent failures. F-SCADA continuously monitors equipment status in OCC. In case of equipment failure, the information is transmitted to OCC in real time and displayed on the monitor with buzzing sound. In addition, F-SCADA terminals are installed at each maintenance office and equipment failure information can be obtained there at the same time as OCC.

The F-SCADA shall directly monitor the main equipment of Signalling & Communication and other safety systems of network.

11.3.20 Recommendation for Communication System

The communication system is the backbone for Signalling & Train Control system, SCADA system, Automatic Ticketing system, Safety & Security system, etc. and also provides communication service for information to passengers, Administrative management, Operation & maintenance, Emergency control etc. which are the required for a high-speed rail network.

The Communication facilities proposed are helpful in meeting the following requirements for:

- Supplementing the Signalling system for efficient train operation.
- Exchange of managerial information
- Crisis management during emergencies
- Passenger information system

Some of the Signalling & Communication system manufacturer company has successfully completed tests to operate its range of mass transit and mainline rail control solutions with the latest Long-Term Evolution (LTE) standard for wireless data communications, commonly known as 4G. The tests were carried out with four leading suppliers with a global footprint – Ericsson, Huawei, Nokia and ZTE. The technical assessments were conducted in line with the rail signalling industry’s Quality of Service (QoS) requirements for the transmission of critical signalling information along track side and other wireless communication with the train.

The LTE-R standard supports high speed and capacity for wireless data transmission networks and offers the ability to consolidate delivery of multi-service traffic into a single wireless network. Well known for its roll-out on commercial mobile networks, LTE is rapidly being adapted for the railway industry for ground-to-train voice and data communications. Operators using LTE will be able to integrate the transfer of safety-critical signalling, closed-circuit television, passenger information system as well as onboard internet services into one network. In addition, operating rail control solutions with LTE-R will enable to enhance system stability and data encryption and security.

In addition to the above, Indian railway is also going for modernisation of the signalling system with LTE in important routes. Indian Railways are processing to execute ETCS Level-2 with LTE in four different sections (Pilot projects) over Indian Railways. However, this work in under tendering stage now.

Global System for Mobile Communications (GSM-R) with limited capabilities, to fourth generation (4G) broad-band systems that offer higher data rates, e.g., Long-term evolution (LTE). It is thus relevant for high speed rail system to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability in future. Hence, modern technologies, such as Long-Term Evolution (LTE), have to be evaluated as possible railway communication technologies to replace GSM-R in the future. GSM-R system can be considered if the LTE system is not full matured at this time of executing the project.

The Communication system for a SilverLine project in Kerala would comprise of, but not limited to, following subsystems for smoother and safely train operation:

- Long Term Evolution (LTE-Mobile Radio Communication System)
- Backbone Transmission Network (with SDH & GbEN)
- Telephone system (IP PBX exchange system)
- Centralised Digital Recording System (CDRS)
- Passenger Address System (PAS)
- Passenger Information and Display System (PIDS)
- Time Distribution System with GPS system
- Closed Circuit Television System (CCTV)
- Facility -Supervisory Control and Data Acquisition (F-SCADA)

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 12
TICKETING AND FARE COLLECTION SYSTEM

12 TICKETING AND FARE COLLECTION SYSTEM

12.1 INTRODUCTION

Kerala’s SilverLine project rail corridor 529.450 km (approx.) between Thiruvananthapuram to Kasaragod is to be planned with a design Speed of 220 kmph and an operational speed of 200 kmph. The travel time will be about approximate 4-hour. The SilverLine project is planned with 11 no of stations.

The rail transport is one of the most important means of transport, has played an important role in the transport industry in India. The railway line and passengers have been increasing year by year in the country. The High-Speed Rail transit system is expected to handle large number of passengers daily. Ticket issue and fare collection will play a vital role in the efficient and proper functioning of the system. To achieve this objective, ticketing system should be simple, easy to use/operate and maintain, easy for accounting facilities, capable of issuing the fare media types selected, easily modifiable for quick fare policy changes and require optimum manpower overall. The Ticketing and Fare Collection systems to be implemented for the SilverLine rail transit system will ensure that:-

- The correct fare value is collected from any of the passenger using the system, and
- No unauthorized persons are allowed to travel on the transport mode.

For public transit operators, automated fare collection (AFC) systems has drastic impact on both the cost of operations and the revenue generation potential. For passengers, fare collection is only a small part of their travel time, but it significantly impacts their overall experience. Customers expect a seamless travel experience. Missed trains due to long lines at ticket vending machines are unacceptable.

The ticketing system is a computerized (Multi-Model) system for effective management of the process of reservation, ticket issuing and inspection with a view to improving convenience of users. The ticketing process shall have both online and In-person’s capabilities, enabling passengers to book tickets online or take it in-person from the ticket window. A passenger with a valid ticket shall enter and exit through automatic gates at boarding and de-boarding stations without any manual intervention by railway staff.

The ticketing system shall be advanced computerized multi-model transport ticketing system for SilverLine rail transit system. Multi-model ticketing system would help SilverLine transit system to provide seamless commuting experience for passengers within Kerala State using a single common mobility card as fare media. The ticketing system will operate using high safety and secured system. So that it can be integrated with ticketing system of other transit operators in Kerala.

Key benefits of automatic ticketing and fare collection system

- Reduction in ticketing cost –Transit operators can lower their ticketing costs with electronic fare media. The reusable smart cards lower the costs of printing, distributing and handling paper tickets.
- Higher revenue collection -Electronic ticketing reduces fare evasion, revenue leakages, and chances of theft of physical currency. The system is automated so that it can reduces the logistical cost of revenue collection compared to paper-based ticketing.
- Provision of real-time ridership data –Electronic ticketing involves automatic recording of passenger entry and exit at the fare gates. This allows the centralized control system to collect real-time ridership data, which can be very valuable in vehicle despatch schedule changes and other key planning's.
- Faster transactions –Use of a contactless smart card/ bank card/ mobile-enabled application allows faster transactions and lower boarding time.
- Ability to offer flexible fare policies –Electronic ticketing enables an operator to implement variable fares based on the time or mode of travel, type of passenger, etc. This is a great advantage because it allows the operator to manage passenger demand by incentivizing travel during off-peak periods or a certain mode.
- Value-added service integration- These functionalities and services can be integrated to Automated Fare Collection system like payment for restaurants, parking, micro-payments for retail purchase etc.
- Loyalty reward programs such as travel discounts, discounts on parking fee, discounts may be available at restaurants etc.
- Highly reliable, scalable, secure and customer friendly facility. The system security shall include, protection against fraud, theft, falsification of data, false accounting, external threats, denial of service, eavesdropping, loss or corruption of information, masquerading (spoofing) and unauthorized access, etc.

12.2 OVERVIEW OF TICKETING SYSTEM

The tickets are most often used for receiving fares in exchange for railway transportation services provided for users. The ticketing system handles reservation, ticket issuing and inspection processes. The ticket system is different in structure according to the operation/ management system, equipment specification and services offered by the operator. The ticketing process are as below:

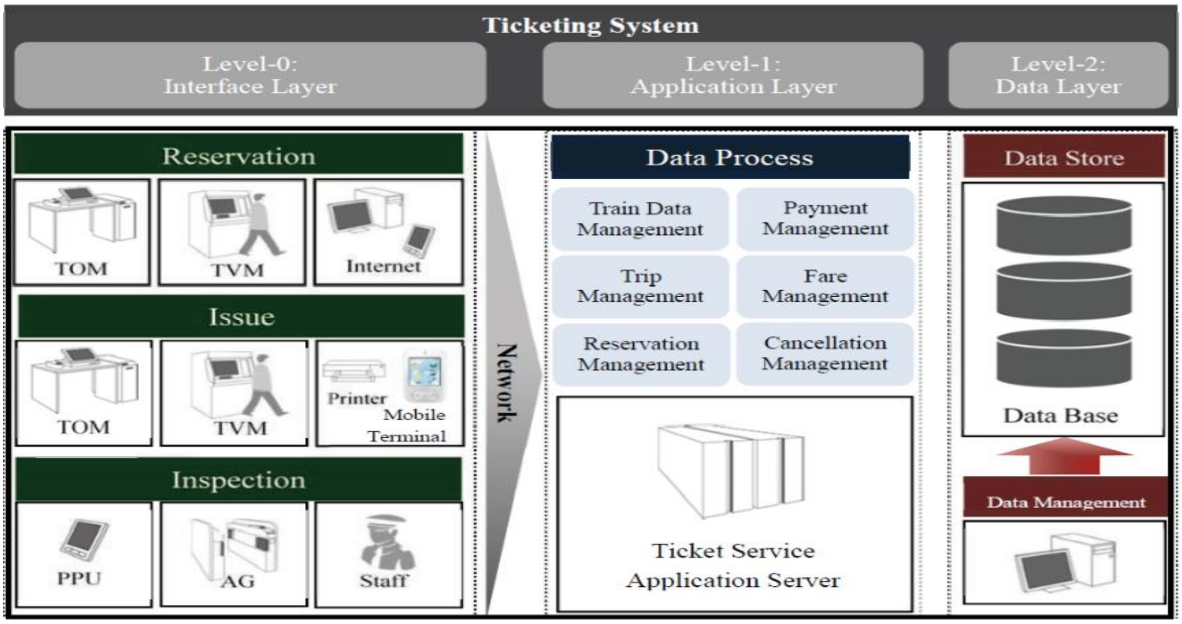
I. **Reservation process:** The process in which passengers book tickets in a prescribed way, by using online booking (by Internet booking) or Ticket Vending machine or ticket office machine or mobile .

II. **Ticket issuing process**: Booked ticket is issued through the printer, Mobile, Ticket Vending machine or ticket office machine according to the reservation number. Whatever may be the mode of booking the reservation and ticket issuing will be processed in a sequence.

III. **Ticket Inspection process**: Passenger tickets are checked to confirm their validity. An inspection is conducted at both the time, during entry and exit in addition to during on board.

The advanced computerized ticketing and fare collection system generally built up from three layers:

- **Interface Level**- Interface between users and application level for facilitating reservation, ticket issuing and inspection.
- **Application level-**Handles requests from interface layer and delivers the results and complete management of data processing for a ticket.
- **Data Level-** Manages the data used on application level. The application server, extract data from the data level, renews and stores the same.



Source: Mum-Ahmd HSR Report

Figure 12-1: Ticketing System Structure

The data used throughout the ticketing system are stored in the database connected to the application server. When any of the processes is done, a relevant channel of the interface layer inquires the application server, and then receives transaction results as an answer from the server. Multiple requests are sent concurrently from station machines and the online system, so the application server needs to respond effectively to them and ensure that no improper transactions occur, including dual issuing.

12.2.1 Ticketing Systems for High-Speed Rail Transit System in Other Countries

According to the operation and management system, service offered to passenger, technology & equipment used, the ticketing system is different in its architecture. Different countries use different system for ticketing and fare collection. The ticketing system mainly depends upon the following points:

- **Ticket medium :** Tickets used by other countries in high-speed railway/ metro are either one/ combination of paper tickets, magnetic tickets, integrated circuit **(**IC) cards and e-tickets by using the internet (online/ mobile app).
- **Reservation and ticket Issuing:** Reservation of ticket can be through ticket windows, TOM/TVMs at station and online system through the Internet/ mobile application.
- **Ticket Inspection:** Inspection of ticket is required at station entry/ exit as well as on - board for checking the validity and data record. The system for Inspection of tickets is dependent upon the medium of the ticket. In case of magnetic ticket or IC card, its validity is checked by a reader equipped at the automatic gate. The validity of an e-ticket is confirmed by reading information printed or displayed on the mobile terminal. On-board inspection (by the conductor) is necessary to check passengers who do not use the seat and train designated on the ticket. On-board inspection has been done by the conductor according to the printed chart of reserved seats., but now the use of Portable Processing Units (PPU) on which the reserved seat information is downloaded from the application server is gradually becoming common to make sure that the passenger’s ticket is consistent with the given information.

Table 12-1: Ticketing system structure for High-Speed railway in other country

Country	Ticket Medium	Reservation	Inspection	Payment
Japan (Shinkansen)	Magnetic, Paper, e-ticket, IC, Mobile Device	Windows, Internet, Ticket Vending Machine	Automatic Gate, Conductor	Cash, Debit/ Credit Card
Germany (Intercity express)	Paper, e-ticket	Windows, Internet, Ticket Vending Machine	Conductor	Cash, Debit/ Credit Card
France (Grande Vitesse)	Paper, e-ticket	Windows, Internet, Ticket Vending Machine	Conductor	Cash, Debit/ Credit Card
UK (Pendolino)	Paper, e-ticket, Mobile Device	Windows Internet, Ticket Vending Machine	Conductor	Cash, Debit/ Credit Card

Country	Ticket Medium	Reservation	Inspection	Payment
Taiwan (HSR)	e-ticket, Magnetic	Windows, Internet, Ticket Vending Machine	Automatic Gate, Conductor	Cash, Debit/ Credit Card

Source: compiled by study team

12.2.2 Existing Ticketing System of Indian Railways

The Indian Railways are among the world's largest rail networks. Indian Railways issued more than 21 million ordinary tickets and more than average 2 million reserved seat tickets per day. Country Wide Network for Computerised Enhanced Reservation and Ticketing (CONCERT) is used for issuing reserve seat tickets. This existing system was developed and is managed by CRIS (Central for Railway Information Systems) . CRIS organization is working under Ministry of Railways. CONCERT is the core of the reservation system and works on interface layer, Application layer and Data layer as shown in the figure below:

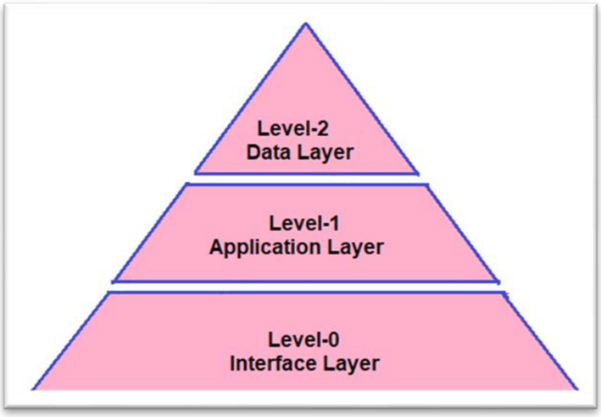
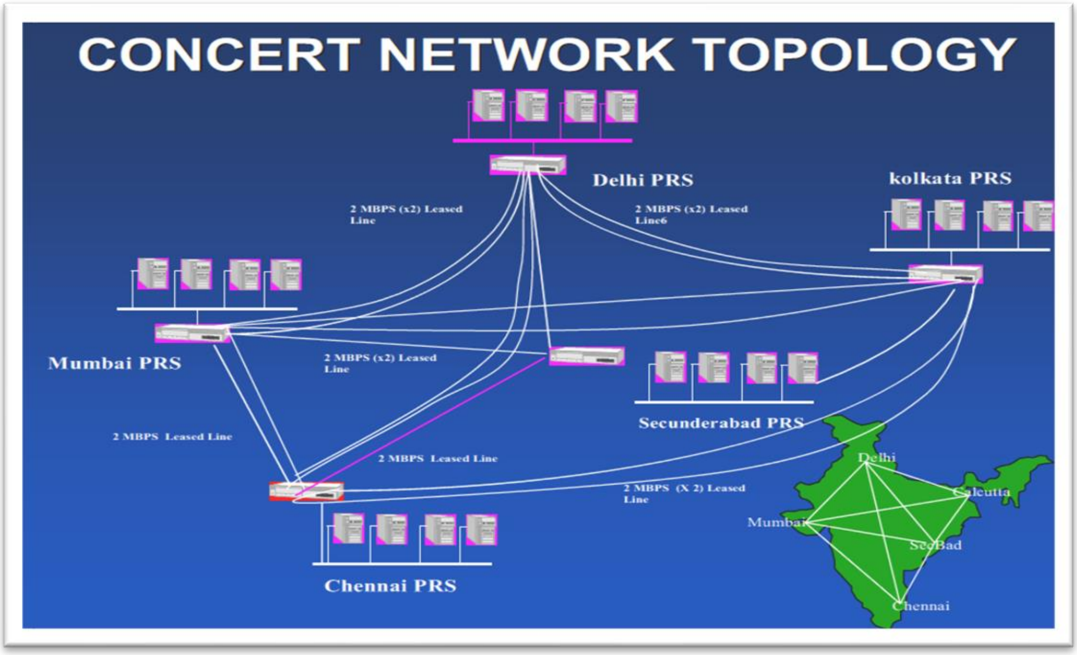


Figure 12-2: Ticketing system Layer

This application was first implemented at the Secunderabad PRS site in September 1994 and subsequently at the other four PRS sites. Currently, the PRS servers are maintained at the five sites in Delhi, Mumbai, Kolkata, Chennai and Secunderabad and operate in a distributed database process environment.



Source: Indian Railways

Figure 12-3: Indian Railways System (CONCERT Network)

Communication of all the terminals with their server was established using Railway/ Department of Telecommunication (DOT) channel lines, fibre-optic cable/microwave channels, switches, modem, multiplexers etc. The inter-networking of five PRS nodes was completed in April 1999. Interconnectivity is established between the five PRS centres over 2 Mbps leased Bharat Sanchar Nigam Limited (BSNL) lines. The system has the capability of issuing reserved tickets from anywhere to anywhere, in any train, date or class between any pair of stations from any booking terminal of the PRS. The main modules of the PRS are the Reservation module, the Cancellation and Modification Module, the Charting Module, the Accounting Module, and the Database Module. Major outputs generated by the system are reservation cum-journey tickets, cancellation/modification tickets, reservation charts and daily terminal cash summary. The system is also capable for generating different types of Management Information system (MIS) Reports.

The computerized Passenger Reservation System (PRS) facilitates booking and cancelling of tickets from any of the 4000 (approx.) terminals (i.e. PRS booking windows) all over the country. These tickets can be booked or cancelled for journeys commencing in any part of India and ending in any other part of India.

Table 12-2: Ticketing system structure of Indian Railways

Ticket Medium	Unreserved Ticket	Reservation Ticket	Ticket Inspection	Payment
Paper, e-ticket, Mobile Device	Windows, Internet ,Ticket Vending Machine	Windows, Internet	Conductor (in Train/ Station)	Cash, Debit/ Credit Card ,One Nation one card, RuPay etc.

Source: compiled by study team

The passenger can book tickets at station terminals, booking agent terminals, post offices and authorized agents linked to the reservation website of IRCTC (Indian Railway Catering and Tourism Corporation) and via mobile phone.

12.3 OVERVIEW OF TICKETING & FARE COLLECTION FOR SILVERLINE

SilverLine rail transit system is expected to be used most often by people who try to use their time effectively than in the existing railways where much time is taken for travel. Such business people tend to use the online system for reservation, rather than waiting in line at ticket windows, so a need for internet reservation is probably greater for the SilverLine rail transit than for existing railways.

SilverLine rail transit system is expected to handle a large volume of passengers. The Ticketing system handles reservation, ticket Issuing and Inspection processes. The ticketing system shall provide world class ticketing facility to the passenger. After booking the ticket either by online / offline, reservation and ticket issuing are processed with a sequence by the central ticketing system server. Passenger's tickets are checked to confirm their validity during the inspection process. Inspection of tickets are conducted at the time of both entering/ exiting the concourse, or on board.

The Ticketing and Fare Collection system of SilverLine are planned to be achieved by the following basic principles:-

- The ticketing system should be computerized centralized ticketing solution system for effectively managing the complete processes of tickets – Ticket issuing, reservation, medium, Mode of payment and Inspection.
- The ticketing system should be able to generate the real time management and financial reports.
- The system with comprehensive features and services running on a user-friendly design and robust platform and architecture, covering databases, web services and interfaces to other operating systems, including web sites, mobile devices, mobile apps, etc.

- The system should be handled all types of ticket solution with dynamic pricing, promotion, discount and other offers.
- Central System in redundant configuration shall be connected with stations systems via BTN (OFC network) .The system should be proven to come equipped with strong Security Features.

The system shall handle all functionalities of the ticketing process, management, access control, fare management, payment, financial requirements, settlement between different registered operators. The system shall generate a financial report and management reports. The system is responsible for internal and external interface with all ticketing process through gateway and third party. The system software and hardware shall ensure, secured transaction, processing of ticket and payment using appropriate high-level security technology. The centralized ticketing server is connected through via backbone transmission network (BTN) with application servers. All the data used in the ticketing process system are stored in a database of centralized ticketing system server. After completion of the ticketing process, centralized server shall communicate the transaction result to the application server. The system shall ensure the ability to obtain complete and clear data backup and recovery of operation process. A central computer system shall be in redundant configuration and located at OCC and BCC.

Station Computer System & Equipment: The station ticketing system shall handle all the fare collection equipment & machines. The station server will control all the activities of all the machines. All the station servers will be linked to the central computer at OCC through the backbone transmission network (BTN). The following mini equipment's will be required at each station:

- Station local Server for management of station equipment and processing of data from/to the station equipment
- Ticket office machine (TOM) for reservation and issue of ticket operated by station staff
- Ticket vending machine (TVM) for reservation and issue of ticket by operation of customer
- Automatic gate (AG) for inspection ticket validation on entry and exit.
- Portable Processing unit (PPU)
- Mobile Ticket Counter (MTC)

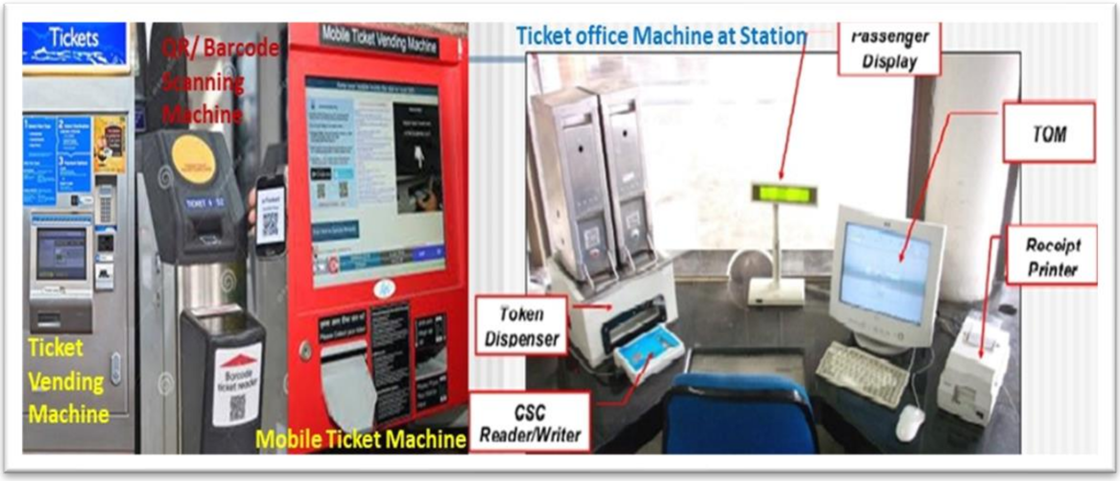


Figure 12-4: Ticketing system equipment

Ticketing Terminals and information Point: The ticketing terminal/ sale point are to be provided at all the stations. All the station should have ticket windows and ticket vending machine/ticket office machine. Provision should also be made for some mobile ticket counter near crowded area in the city. The passenger information display system should be provided at each station, where passenger get all information of train schedule, timing, tickets, etc.

Ticket Booking System: The ticket booking facility shall be provided through on-line, offline, ticket windows, Mobile ticketing counter, ticket vending machine/ticket office machine. The ticket medium shall be Paper, Magnetic, IC and e- ticket (by mobile app, computer). Ticket medium depends upon the booking process chosen by customer. All the necessary information should be mentioned in all types of tickets. All the tickets should be provided with Security Code (SC) /Quick Response Code (QR)/ Barcode for verification. The passengers shall be able to make ticket payment by cash, credit/ debit card and net- banking.

Issuing of Ticket: All types of tickets shall be with necessary details as mentioned below:

- Ticket number & Passenger name record (PNR)
- Passenger Name, Age & Sex (as per identity proof)
- Details of Train, Coach & Seat Number
- Train Departure & Arrival time
- Boarding Station and De-boarding Station
- Date & Time of booking and Travel date
- Fare and Paid Service detail
- Security code/ Quick Response Code (QR)/ Barcode etc.

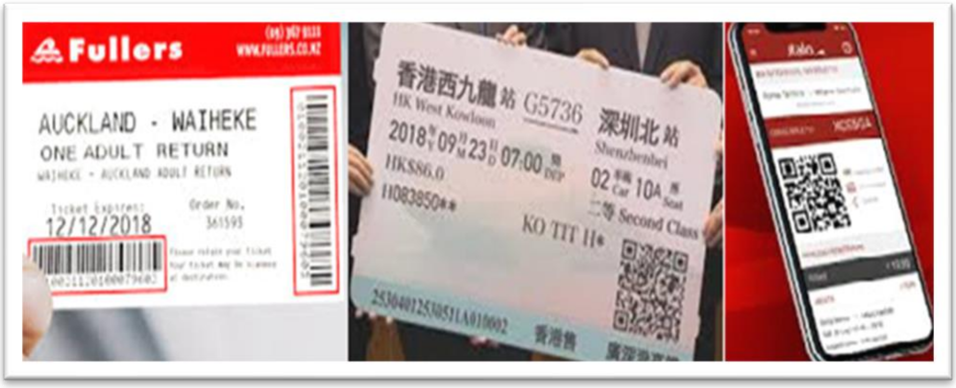


Figure 12-5: Sample of ticket with security code/ QR/ Barcode

Inspection of Ticket: The inspection of the ticket shall be administered at station entry and exit points by automatic gate and on board by conductor by manually / by using the Portable Processing unit (PPU) /Mobile ticketing (Scanner & Printer). These devices are commonly used for on board inspection of the ticket, which download the reservation information from main ticketing server to make sure that tickets are consistent with the given information.

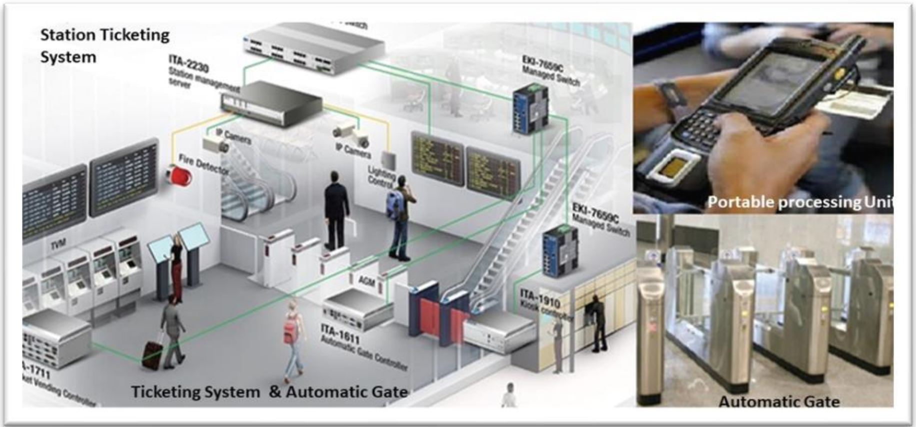


Figure 12-6: Automatic Gate & PPU

Facility for passenger: The passengers can book reserved/ unreserved ticket, bulk ticket, multiple trip/monthly ticket, promotion/ discounted ticket etc. The system shall provide for cancellation/ modification/ re-scheduling, refund and surcharge etc. During online and offline ticketing process passengers have the facility to select their seat. The system shall provide information like coach wise seating plan view, pricing details and availability of the seat to allow the user for selecting the seat at time of booking.

12.3.1 Passenger Ticket

SilverLine rail transit system is being used by the passenger for travelling between Thiruvananthapuram to Kasaragod. The passenger need to book the ticket for short distance and long distance journey. The two type of tickets should be issued as per passenger requirement such as:

- Reserved Ticket
- Unreserved Ticket

The system should be allowed the passenger to book the ticket in any one combination of any Type of Tickets ,Printing Medium ,Mode of payment as per their choice.

Table 12-3 : Ticketing system structure of SilverLine

Type of Ticket	Ticket Medium	Ticket Issued	Ticket Inspection	Fare Media Payment
Reserved/ Unreserved Ticket	Paper, E-Ticket, Mobile Apps /Mobile Web, IC, Magnetic	Windows, Internet, Mobile application, Ticket Vending Machine, Ticket office machine	Conductor (in Train & Station)	Cash, Debit/ Credit Card, Smart Card, One Nation One Card, RuPay etc.
Note: The Ticketing system shall be follow the Rule/ Guideline & Business rule of SilverLine/K-Rail.				

The ticketing system details are mentioned below:

- **Ticket booking system:** The ticket booking facility shall be provided through on-line, offline, ticket windows, Mobile ticketing counter, Ticket vending machine, Ticket office machine (TOM). All the necessary information should be mentioned in all types of tickets.
- **Reservation of Ticket:** The system should be allowed to passenger the facility to select their seat. The system shall provide information regarding coach wise seating plan view, the pricing details and seat availability. The system should allow the user to make an informed selection of seating to purchase at that particular time of booking.
- **Security Code on Ticket**: All the tickets should be provided with Security Code/Quick Response Code (QR)/ Barcode for verification
- **Ticket Cancellation / Modification:** The system should allow the passenger for cancellation /modification in the ticket by using the same procedure of booking.
- **Ticket Medium**: The ticket medium shall be Paper, Magnetic, IC and e- ticket (by mobile app, computer). Ticket medium depends upon the booking process chosen by customer. All the necessary payment information should be mentioned in all types of tickets.

- **Information on Ticket** : The necessary information should mentioned on the ticket like passenger detail, train detail, fare detail, seat details, station details and other relevant travel details which is applicable.
- **Mode of Payment** :The passengers shall be able to make ticket payment (fare media) by cash, credit/ debit card, smart card, one nation one card , RuPay and net- banking etc.
- **Inspection of Ticket:** The inspection of the ticket shall be administered at station entry & exit points by automatic gate and on board by conductor by manually or by using the Portable Processing unit (PPU) . These devices are commonly used for on board inspection of the ticket, which download the reservation information from main ticketing server to make sure that tickets are consistent with the given information.

12.3.2 Ticket for Feeder/City Bus

Some of the passenger come from the nearby city of SilverLine, need Metro Train, City & Feeder Bus to travel from city to Silver -Line station and vice -versa. So all the stations should have proper arrangement for a feeder/city bus for the passenger. The passenger can purchase the ticket from any medium like- online , cash, Smart card, etc. The EMV based smart card open loop AFC system (AFC feeder) should be implemented across all these feeder & City buses. This common mobility card will help the passenger for payment for Metro, City & feeder buses. The fare media would include EMV smart cards , NFC and mobile ticketing system to achieve common mobility.

Figure 12-7: City/ Feeder Bus Service

12.3.3 Parking Ticket

Some of the passenger need vehicle parking facility at SilverLine station for parking the vehicle. The vehicle parking facility should be provided at all the stations. EMV smart card based AFC system will be extended across all parking facilities provided by SilverLine near to station. AFC parking should accept common mobility card as payment media to pay for parking charges. The fare media would include EMV smart cards , NFC, Cash and mobile ticketing system etc.

12.4 TICKETING & FARE COLLECTION SYSTEM FOR SILVERLINE PROJECT

The ticketing & fare collection system proposed for SilverLine project is with high importance on the safety and convenience of users. The ticketing system should be highly functional and time-proven with all types of ticketing service. The Ticketing and fare collection system for SilverLine rail transit system should be provided with following necessary main subsystem like:

- Central Computer System (CCS)
- Smart Card (EMV based)
- Mobile Apps/ Mobile web Application
- Station Computer System (SCS)
- Ticket Office Machine (TOM)
- Ticket Vending Machine (TVM)/ Self- Service Ticketing KIOSKS
- Mobile Ticket Counter (MTC)
- Portable Processing unit (PPU)
- Automatic Gate (AG)

Table 12-4 : Function of ticketing Equipments

S.No	Name of Equipment	Function
1	Central Computer System(CCS)	Management of all ticketing equipments and station computer systems. Management of complete functionality of ticket & fare collection system and interface with external & internal systems.
2	Smart Card (EMV based)	Additional medium of payment for ticket and other service of Silver Line.
3	Mobile Apps/ Mobile web Application	Information of SilverLine network and service. Online booking the ticket and other service.
4	Station Computer System (SCS)	Management of station ticketing equipments and processing of data from/to the station equipments ticketing systems from OCC

S.No	Name of Equipment	Function
5	Ticket office Machine (TOM)	Reservation and issue of ticket by operation of station Staff
6	Ticket Vending Machine (TVM)/ Self Service Ticketing KIOSKS	Reservation and issue of ticket by operation of customer
7	Mobile Ticket Counter	Reservation and issue of ticket by operation of customer
8	Portable Processing Unit (PPU)	Validation ,Reservation and issue of the ticket by operation of conductor on the train.
9	Automatic Gate (AG)	Inspection and validation of ticket at entry and exit point of station.

Source: Compiled by Study Team

12.4.1 Centralized Computer System (CCS)

The system shall handle all functionalities of the ticketing process, Accounting management, Access control, Fare management, Maintenance management, Financial requirements, Settlement between different registered operators & security and access rights management application. The system shall generate a financial report and management reports. The system is responsible for internal and external interface with all ticket processing through gateway and third party. It is composed by the following parts:

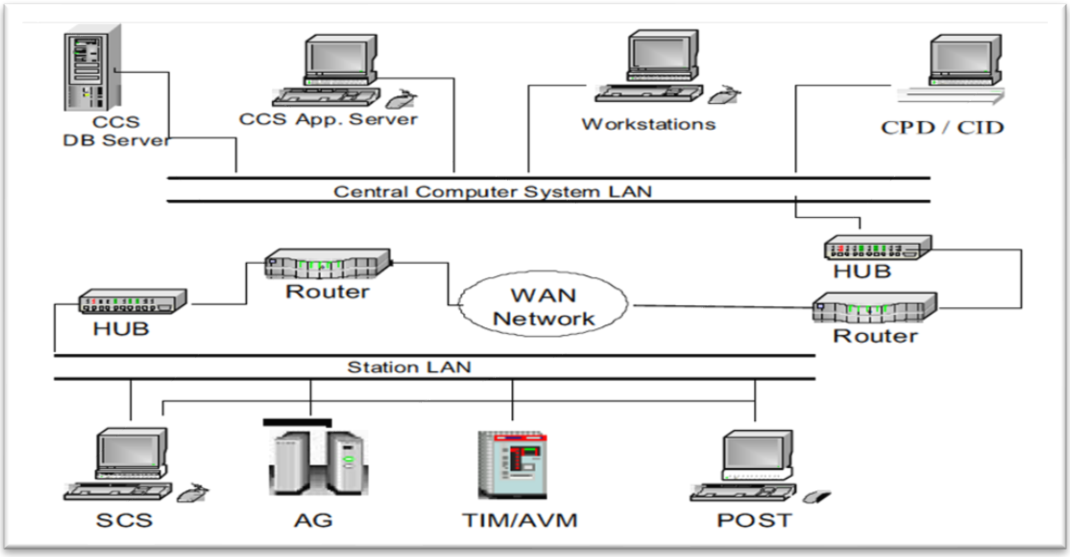
- **Hardware:** It is able to carry all the required applications and database engine even the data backup and recovery solution provided
- **Software:** Software applications is that cover all the business needs of ticketing system. They will be modular, web based and support the service oriented architecture that enable building block concept.

The system software and hardware shall ensure, secured transaction, processing of ticket and payment using appropriate high-level security technology. Ticketing system will be standalone and not interrogable with other IT system. The Station computer system is connected to a centralized computer system via BTN. Where all the transaction is stored, studied, the operation and monitoring are performed and the reports give the operation results. The main feature of this system will be security and reliability in order to ensure the data safety. The system also manages communications with a board variety of external systems to avail the data transmission for the system integration. The centralized and station ticketing system will be synchronized with the Master clock system.

The central system of ticketing system shall be interfaced with the banking system. The banking interface shall be required for enabling top-up channels like acquiring, issuing mobile banking, payment gateway and other . The banking interface shall also be used for customer service.

The ticketing and fare collection system shall integrate and synchronize seamlessly with a collection of multiple systems, like the inter-site transmission network, master clock system, power supply system, main earthing facilities, cable routing facilities, fault monitoring system etc.

The centralized ticketing server is connected through via backbone transmission network (BTN) with application servers. All the data used in the ticketing process system are stored in a database on centralised ticketing system server. After completion of ticketing process, centralized server shall communicate the transaction result to the application server. The system shall ensure the ability to obtain complete and clear data backup and recovery of operation process. A centralized ticketing system shall be in redundant configuration and located at OCC and BCC.



Source: compiled by study team

Figure 12-8: Representation Ticketing & Fare collection system architecture

12.4.2 Smart Card for SilverLine

The advance ticketing system should be implemented across all the stations of SilverLine. This system should enable the smart card as additional fare media for passengers to pay for the intended travel. The Smart card will store information about passenger along with balance amount. This information will be read by validators installed at all stations. Depending on business rule set by SilverLine/ K-Rail organization, a passenger would be allowed/ denied access to the station based on information stored on the card, especially balance amount. To provide additional flexibility following fare media options would be offered to passengers in addition to EMV smart cards.

For considering interoperability ,Scalability and reliability offered by EMV (EMV originally stood for "Europay, Mastercard, and Visa" based) open loop ticketing system should be required. EMV cards are smart cards (also called chip cards, integrated circuit cards, or IC cards) that store their data on integrated circuit chips, in addition to magnetic stripes (for backward compatibility). The state-of-art solution in uniquely designed to demand of revenue services and keeping in mind the modern transit operation. The open loop based ticketing system across all the stations of SilverLine. Due to non-proprietary standards this system can potentially be extended across other public transport services in Kerala such as Feeder buses, City buses, Metro etc. and also reduce operational issue and thereby enhance the passenger experience.

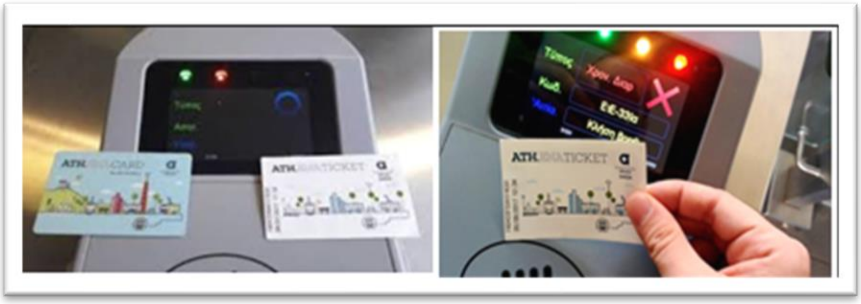


Figure 12-9: Sample of Smart Card and Paper Ticket

Smart card (Common mobility card) can be used as payment media across all merchant establishments accepting cards for payment. The citizen can perform all retail transactions, utility payments, etc. through common mobility cards. The common mobility program should provide seamless, integrated travel experience for passengers of SilverLine as well as provide an alternate option for payment needs.

12.4.3 Mobile Apps/ Mobile Web Application

The SilverLine mobile application (Mobile App) shall be developed by K-Rail. The mobile application can help the commuters to know about SilverLine from anywhere and everywhere and use it in a better and easy way. Mobile applications are an easy source of information and easy means of performing a task while on the go. While travelling in a Silver- line rail transit system, there can be many things commuters need to know about. A commuter may want to know the SilverLine station map to know which all locations aggregate trains can connect etc.

The proposed SilverLine Mobile application should be multiple features which will help commuters understand their journey within SilverLine and will make it easy for them to use the SilverLine. The mobile application Salient features are like:

- Display the route map and train information of SilverLine network
- Information of connectivity and feeder bus services
- Calculation route from any source to destination along with cost of Journey
- Online Booking the ticket and transactions
- Recharge the smart card and book the other services of SilverLine
- Get the loyalty points and promotion offer for using Mobile application

Figure 12-10: Mobile ticket

The SilverLine/K-rail mobile phone app shall be developed. It shall aim to extend the experience for the passengers, and this ticketing component should start from when they plan travel and check for information relating to the train schedule, operating hours, timings, direction instructions to get there, facilities, amenities in SilverLine trains and Station's premises.

The online ticketing module should be able to support website for use via a mobile device, and integrate with SilverLine Smartphone App (running on iOS / Android / Windows) through a set of ticketing system applications. The mobile web and mobile app ticketing feature should allow SilverLine ticketing system to detect paid users for entry in platform paid area/Train, by scanning off passenger's mobile screen, or better form of access control.

The ticketing industry is continuously evolving, and it's not just the type of physical ticket that is changing but the very notion that many passengers don't even want one or need one, and certainly don't want to wait in line to purchase a piece of custom media from their transit agency.

Today, more and more users are turning to queue-free contactless payment options, which are replacing traditional paper or smart card tickets. With E-tickets, mobile tickets, account-based ticketing, contactless EMV, the number of BYOT (Bring Your Own Ticket) options keeps on rising, which is a new challenge for agency staff to prioritise and keep up with when procurement intervals can be between 5 and 15 years for traditional core fare collection systems.

12.4.4 Station Computer System

The Station Computer system (SCS) describes a wide range of functionalities needed in a Ticketing and automatic fare collection system, including the control of Automatic gates and all station equipment. The SCS is the manager and controller of the station in which all required applications, a database engine for automatic station’s business process related to ticketing system, the exchange of data from centralized computer system (CCS) to station’s toll equipment and vice -versa are installed.

The Station Computer System (SCS) will carry out the following functions :

- Station configuration using software
- Distribute the fare structure and blacklist files to the station devices for excess fare.
- A number of present configurations (new equipment in/out of service) per station will be stored. Application of each configuration will be effected either automatically, depending on the time of day, or manually by the management centre (SCS)
- Display the current operational status of the entire new equipment in the station.
- Remote control of equipment for setting in-operation/out of operation or in status of maintenance.
- Retrieve and process (upload to the management centre) all data from the existing station computer.
- Define, perform and monitor specific tasks prepared for the new Ticketing and fare collection equipment, developed and scheduled by the management centre (SCS)
- Display, record and announcement of all alarms, events and fault conditions related to new AFC equipment and relay specific alarm conditions immediately to management centre.
- All record alarms, events and faults conditions will be automatically transmitted on specific time intervals to the Central Computer System (CCS). The examination of this recorded information either on station level or per specific equipment will be effected through an interrogation session.
- Record all authorized entry access to new equipment. Any unauthorized access to new equipment will be triggering the alarm system and will be recorded.
- Store and download current fare table data for all new machine types, including card black lists.

- Retrieve, store and transmit to management center all transactions- recorded data (Accounting) from all the new equipments.
- Retrieve and store and transmit to the management center of all recorded data concerning money vault operations.
- Printout of recorded cases concerning alarm triggers, recorded events and faults conditions.
- Date and time synchronization (of all new equipment and existing station computer)
- Automatic printout of accounting activities at the end of the day or as per requirement of management.
- System shall handle all transactions for multiple applications and settlement between different registered operators and systems.

12.4.5 Ticketing Office Machine (TOM)

The ticketing office machines will be installed in the ticket office at each station. The ticket office machine provided should have at least two at each ticket office with printing facility, ticket reader machine and cash handling machine, so that in case one of the ticket office machine is failed then another system can be accessible. The EMV smart card issuing facility shall be provided. The following minimum facilities for passenger should be provided at ticket office like:

- To purchase all types of travel ticket
- To modify, reissuing, validation and printing of travel ticket
- To purchase other facility tickets and paid services at stations
- To purchase an EMV smart card, reissuing, blocking of the card, validation and reloading card value etc.

Ticket office shall be provided at each side of station entry with full equipment for ticketing system. The Ticket office machine should be with following mini function like:

- Maintenance of the database
- Retrieving the last couple of transactions of EMV Smart card
- Reading of EMV smart card validity and balance value
- Accepting of all types of payment mode
- Management of cash and receipt
- Report management, etc.

12.4.6 Ticket Vending Machine (TVM)/ Self Service Ticketing KIOSKS

The basic objective of the Ticket Vending Machine (TVM) is to issue tickets and accepting all types of payment mode. Ticket Vending Machine (TVM) should provide the convenience for the passengers to procure ticket on their own, without the need to queue at the ticket office/ ticket sale counter. TVM provides the international standard service to the passenger and save the time of passenger.

During the whole sales process of ticketing, the TVM informs the passenger about the operation by means of the display. All the information and all purchasing method received by the passenger shall be configured to the SilverLine operation required. The passenger selects the purchase option by pressing the external buttons around the TVM screen. The selection process generally consists of a sequence of messages in the display through which the TVM request the passenger to define the relevant selection like Type of ticket, Travel information, Ticket price, medium of payment, Passenger information etc. When passenger selection has been completed and paid the ticket amount, the TVM issues the ticket to the passenger. The TVM/ KIOSKS is able to sell multiple ticket (Configuration parameter) at one time.

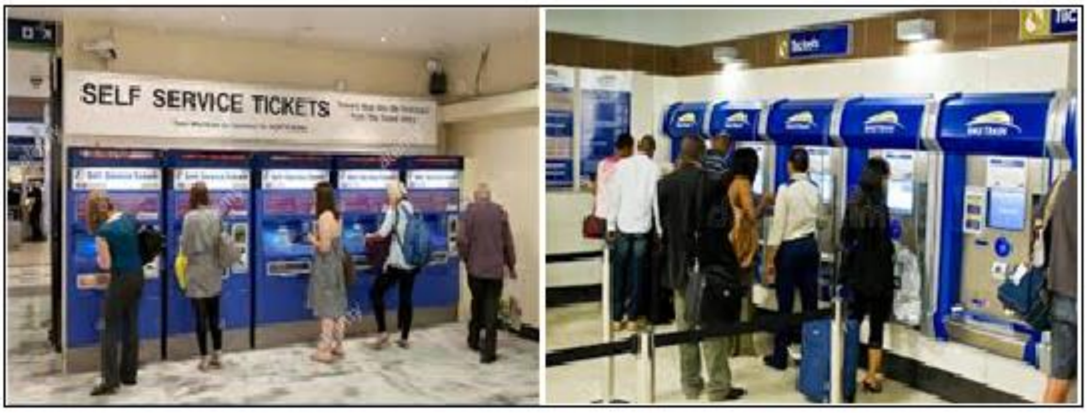


Figure 12-11: Automatic tickets /Self Service Tickets (KIOSKS)

Ticket Vending Machine (TVM) will be communicating with the Central Computer System (CCS) and the Station Computer System (SCS) according to the system design configurations/ project requirements. All the ticketing machine and equipment update the real time updated the information to SCS and CCS database.

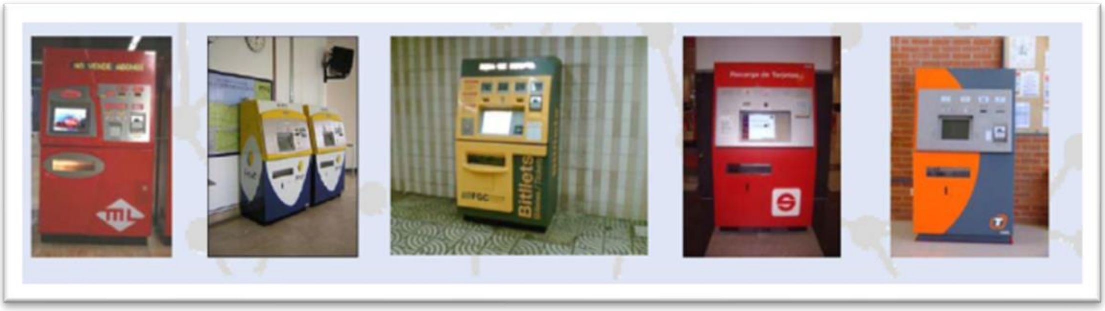


Figure 12-12: Ticket Vending Machine (TVM)

Ticket Vending Machine(TVM)/ Self Service Ticketing KIOSKS should be provided with the following main features like:

- Ergonomic design and easy to use for all passengers and all the rest of TVM user, including the reduced mobility people and other disallowed and the technical personnel.
- Easy operation for passengers to purchase tickets for the journey. The machines shall accept payment in the form of bank notes, coins and credit / debit cards and shall interact with the passengers via a touch screen display and receipt printer.
- The bank note reader shall accept notes inserted in any orientation (any way up or round) and change shall be provided via a combination of note and coin re-circulating mechanism, which minimizes the number of times the station staffs need to replenish the machines with change.
- A reject button shall be provided to enable a passenger to abort a transaction before a ticket issue cycle has commenced.
- System should be high operating speed and high reliability. The touch-point including the screen interface should be customizable in terms of the text, graphics and video.
- Security in operation, including the identification systems, the reloading operation and other maintenance operations.
- Modular design that allows easy replacement of parts, which gives a very high figure of availability.
- On-line customization of tariffs types and other configurations as per time -to time requirements of project.
- The operator accesses to the TVM through a password and identification card for monitoring, maintenance and collection etc.
- The TVM will permanently store all the event that might occur. Events should be understood as : sales, collections ,refill of change, reasons for output of operations, technical alarms, identification of the operator , the actions of the operator etc.

12.4.7 Mobile Ticketing Counter

The Mobile Ticketing Counter provided the extra facility to SilverLine passenger for purchase the ticket near to home or city for that no need to visit the station for purchasing the ticket. The Mobile Ticketing Counter system is flexible to provide a mobile setup to support each ticketing counter stationed outside the station areas. Such mobile counters could also be deployed near crowded area/ heart of City / City Central for Silver Line passenger. The basic objective of the Mobile Ticketing Counter (MTC) is to issue tickets and accepting all types of payment mode. The functional working of Mobile Ticketing Counter functions is same as Ticket Vending Machine (TVM). Mobile Ticketing Counter should provide the convenience for the passengers to procure tickets on their own, without the need to queue at ticket office/ ticket sale counter. The total numbers of Mobile Ticketing Counters are decided during execution or as per traffic report.

12.4.8 Portable Processing Unit (PPU)

The reservation is locked when the prescribed time before the departure time of the train is over. The Central Computer System shall be delivered the Reservation / Booking Ticket chart. This chart to be used by the conductor for on-board inspection. The conductor checks tickets against this chart as per the details provided in the chart. Inspection of Ticket on board by conductor by manually or by using the Portable Processing unit (PPU). These devices are commonly used for on board inspection of the ticket, which download the reservation information from main ticketing server to make sure that tickets are consistent with the given information. If seat available, conductor can allot the seat to the new passenger with the help of the PPU and PPU shall be updating the same to a ticketing server in real time.

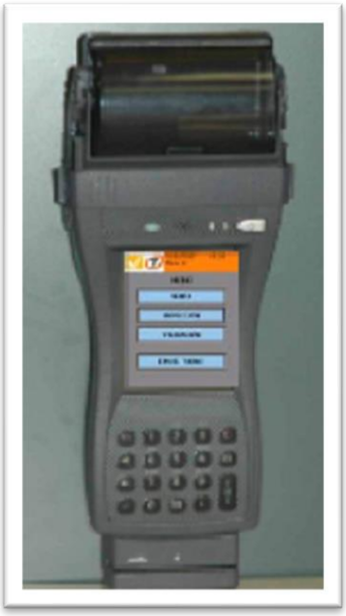


Figure 12-13: Portable Processing unit (PPU)

The status of seat reservation changes as reservation data is input from other stations after the train leaves the starting station . The SilverLine train will run about 529.450 km (approx.) from the starting station to the terminal in approximately 4 hours. There will be 11 main stations on the route. This means that the train runs between two stations in average 25-30 minutes, including the stoppage time at the station. Therefore, passenger will change in a short time, so the changing information on reservation needs to be delivered to the conductor in the train on a real-time basis. That's why the information of PPU's is necessary. The use of PPU always make it possible to renew the reserved- seat information before the train reaches the next station.

12.4.9 Automatic Gate (AG)

For access to transportation system, it will be necessary to validate tickets at the entrance of platform gate. Gate arrays shall be the normal-means of controlling entry to and exit from the paid areas. Control shall be by means of actuating a physical barrier on recognition of a valid ticket by the gate. Where required, barriers shall be provided to separate paid and unpaid areas of the concourse. The barriers shall meet local public safety requirements and be aesthetically merged with station engineering. The barrier shall be a retractable flap type. The gate shall be capable of operating either normally open or normally closed. At entry/ exit, the valid ticket shall be presented by the passenger at Automatic Gate (AG). The Automatic Gate will have a display (Screen) and ticket reader (scanner) on gate unit, that scan and validate the ticket. The passenger information display (LCD screen) shall be, located on top of the gate flush with the top panel.

All the validators will record all the events during the operation. All this information will be sent to the Station Computer System (Station Control Unit) . It will send this information to the central server through the LAN. The gates will give information to the Station Computer System, and the Station Computer System shall be transferred all data to the Central Computer System Via BTN.

Automatic Gate should be provided with the following main features like:

- At entry , exit gate validators will be integrated with Automatic Gate Controller Unit depends on the requirements with Entry gate, Exit gate or Bi-directional gate. Validator’s components should only be integrated with gate controller.
- At entry and exit QR-code/ Security Code /Bar code readers will be integrated with Automatic gate for Reading codes.
- The End Display shall be signified the mode of operation of the gate, either entry or exit or no exit in either direction. Option for configurable passage direction of Station Computer System and Central Computer System.
- Speaker should be integrated with gate play appropriate sound for usage.
- Alarms/ Alerts for tailgating , failures should be captured and reported with to SCS and CCS .
- Gate should be open flips during emergency mode either through hardware emergency trigger or through software remote commands.

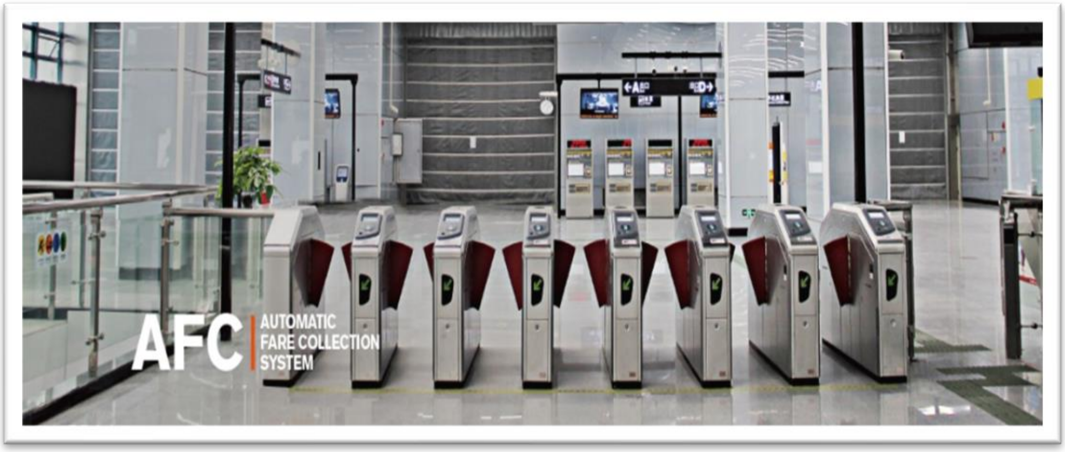


Figure 12-14: Automatic Gate System

The gates shall be retractable type with material of enough strength for use in a mass transit system. The flap of a gate shall in no case get stuck in the slot meant for flap movement. There shall be a shock absorber to reduce the shock and sound associated with the arresting of the arm and mechanism in the closed position. This device shall not impair the passenger designed flow rate. Flap design should be sturdy to withstand a peak hour rush. No possibility of injury to passengers. The barrier shall normally be mounted in such a way to make gate user friendly, if the barrier is forced open, no damage shall happen to gate components and gate should automatically restore to normal. An alarm should be generated during force opening.

12.4.9.1 Different Mode of Automatic Gate (AG)

The gate has the possibility of run under different functioning modes, depending on the gate situation or the station needs. The gate should be configured in any of the below modes in either direction depends the commissioned flap gates:

- Control Mode : In this mode , the entry / exit is controlled through validation of ticket medium
- Free Mode: In this mode, the entry exit is free without any validation
- Forbidden Mode : In this mode , the entry/ exit is forbidden
- Special Mode: It shall be possible to operate the system in following special modes through Station Computer, Central Computer and Automatic gate will be defined in SilverLine/K-Rail business rule on the operation.
- Emergency Modes: In this mode, all gates should be open , should allow passenger for entry and exit without any validation. Gate controller should have interfaced with emergency button (PUSH button) from the Ticket office/ Controller room to open the gate during station emergency and Flap gates should be kept open.

During the power loss AG should shut down gracefully through the UPS backup and also complete the transactions . In case of total power failure to gates, the gates shall open to allow unrestricted user access. All latch gates shall automatically unlatch where electric locks are installed. The engineering of the gate arrays should be such that the passenger uses reader placed on the right hand side while passing through the gate. The display and Ticket reader associated with each gate shall be grouped such that they bias the passenger towards the aisle through which the passenger should pass.

12.4.9.2 Type of Automatic Gate

The station gates should be fully control in the station computer ticketing system. The gate shall be capable of being switched by the station computer from entry mode exit mode and vice-versa depending on the operational requirements of passenger flow. Two gate cabinets work together to provide the required functionality of an automatic gate. In the array of gate, the total number of cabinets used is equal to the total number of gates plus one.

- **Normal (Entry & Exit)** : The normal width gate shall have entry gate and exit gate will be configured only to allow entry, exit from paid area and will have gate validators integration to unpaid area entry/ exit by Ticket.
- **Bi-directional Gate for Disabled (wheeled chair/luggage):** This wide gate will have extended flap gate wing to provide broader space in the passenger aisle to allow those passengers in a wheel chair or with luggage to validate their ticket and gain directional access to, or exit from the paid area. Wide gates should be designed as per statutory laws of physical disabled person on wheel chair.
- **Staff/ Emergency Gate:** This gate normally using by the authorized staff as well as during emergency situation. The gate kept open during emergency situations.

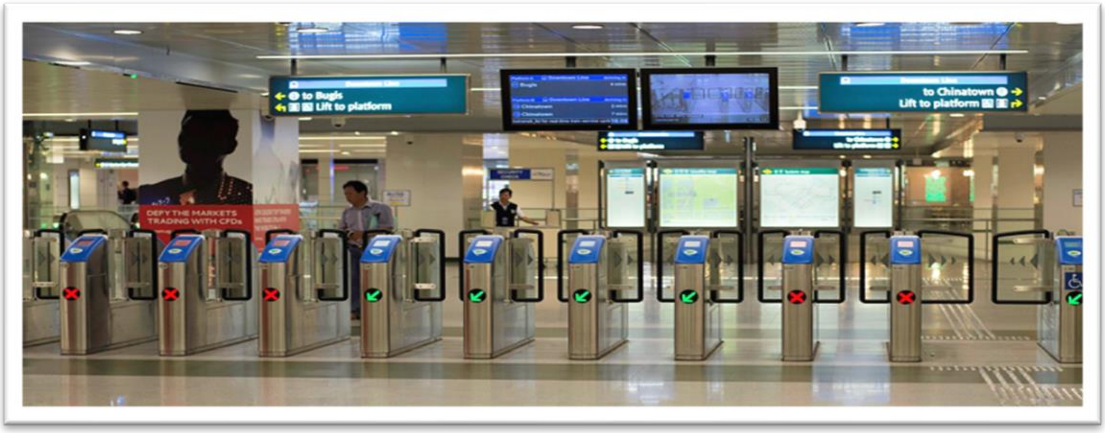


Figure 12-15: Automatic Gate (AG)

Dimensions and spacing – Outside dimensions of the gate cabinet shall be generally based on following criteria:

- Light of aisle = 1900mm
- Normal Gate Width =550-580mm
- Wide Gate Width =900mm-960mm
- Height=1000-1080mm

Details of minimum Automatic gates (AG) proposed for SilverLine stations as per traffic projection are :

Table 12-5 : Details of Automatic Gate (AG) at Stations

S.N	Name of Station	Peak Hour Boarding	Peak Min Boarding	Peak Hour Alighting	Peak Min Alighting	Entry Gate	Exit Gate	Dissabled/ Luggage /Emergency Gate	Total Gate
1	Thiruvananthapuram	2290	115	2120	106	6	6	4	16
2	Kollam	740	37	730	37	2	3	2	7
3	Chengannur	500	25	490	25	2	2	2	6
4	Kottayam	730	37	740	37	2	3	2	7
5	Ernakulam	2310	116	2300	115	6	7	4	17
6	CIAI-Kochi Airport	500	25	500	25	2	2	4	8
7	Thrissur	1010	51	1060	53	3	4	2	9
8	Tirur	280	14	270	14	2	2	2	6
9	Kozhikode	1240	62	1300	65	3	4	2	9
10	Kannur	1230	62	1310	66	3	4	2	9
11	Kasaragod	580	29	630	32	2	3	2	7
12	Depot (Test Lab)					2	2	2	6
TOTAL		11410	571	11450	573	35	42	30	107

Assumptions:	
1	Minimum two Entry gate at each station
2	Minimum two Exit gate at each station
3	One Disabled/ Luggage at each station
4	One Emergency/ Staff gate at each station
5	Throughput of Automatic gate 20 passenger per minute
6	Peak Minute traffic = 5% of Hour traffic

Details of other equipment (minimum) required for stations like-Ticket Office Machine (TOM), Ticket Vending Machine (TVM)/KIOSKS and information centre proposed for Silverline as per traffic projection.

Table 12-6 : Details of Ticket Machines (TOM/TVM/KIOSKS) at Stations

S.N	Name of Station	Peak Hour Boarding	Peak Min Boarding	Ticket office Machine (TOM)	Ticket Vending Machine / KIOSKS	Information Center
1	**Thiruvananthapuram**	2290	115	2	6	1
2	**Kollam**	740	37	2	3	1
3	**Chengannur**	500	25	2	2	1
4	**Kottayam**	730	37	2	3	1
5	**Ernakulam**	2310	116	2	6	1
6	**CIAI-Kochi Airport**	500	25	2	2	1
7	**Thrissur**	1010	51	2	4	1
8	**Tirur**	280	14	2	2	1
9	**Kozhikode**	1240	62	2	4	1
10	**Kannur**	1230	62	2	4	1
11	**Kasaragod**	580	29	2	2	1
12	**Depot (Test Lab)**			1	2	1
TOTAL		**11410**	**571**	**23**	**40**	**12**
Assumptions:						
1	50% Passenger booked the ticket by using Mobile/Web applications and balace by using					
2	TOM/TVM/Kiosks 2-5 transaction per minutes					
4	Peak Minute traffic = 5% of Hour traffic					

Note: In addition to above, more equipment/systems may be required as per final station layout, entry & exit plan of stations and traffic projection report etc. The equipment quantity required should be reviewed at the time of execution of the project based on current traffic projection report.

12.5 ADOPTABLE STANDARD SPECIFICATIONS

The most important standards to be applied for Ticketing & fare collection systems are like:

- EN 50126 (Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS))
- EN 50128 (Railway Applications - Communication, Signalling and Processing Systems - Software For Railway Control And Protection)
- EN 50129 (Railways applications – Communication, Signalling and processing systems – safety related electronic systems for signalling)
- EN 50159 for Railway Applications - Communication, Signalling and Processing Systems

These define the RAMS (Reliability, Availability, Maintainability and Safety) requirements and requirements for designing the safety critical system. The other standards to be applied for Ticketing and fare collection system are:

- EN 349 for Safety of machinery. Minimum gaps to Avoid crushing of parts of the Human Body

- EN 547-1&2 for Safety of machinery. Human Body measurement. Principle for determining the dimensions required for opening for whole body access into machinery and access into machinery
- EN ISO 11064 -1,2,&3 for Ergonomic design of control centres. Principle for the design of control access, arrangement of control & layout
- EN ISO 13406-2 for Ergonomic requirements for work with visual display based on flat panels- Ergonomic requirements for flat panel display
- EN ISO for Ergonomic principle in the design of work systems
- TS 102 610 for usage of the User to User Information Element
- EN 50122 for Railways Applications Fixed Installations - Electrical Safety, Earthing and the Return Circuit
- EN 50121 for Electromagnetic Compatibility
- EN 50125 for Railway Applications - Environmental Conditions for equipment
- EN 50261 for Railway Applications - Mounting Of Electronic Equipment. General Product Information
- EN 55264 for Railways fixed equipment – telecom wires for underground networks

All safety critical equipment shall be designed to conform to fail- safe principles in respect of RAMS, manufactured/OEM, validated to meet the safety Integrity level, in compliance with relevant latest version of international standards like British Standards ,European Standards (EN), Indian Railway Standards (IRS), international Electromechanical Commission (IEC) standards, International organization for Specification (ISO) standards, International Union of Railways (UIC) and other international standards that are widely accepted for High-Speed rail transit system.

The ticketing and fare collection system shall be fully complied with cyber security requirements of the following standards.

- ISO 27001 & 27002 for Information Security Management System and technology-Security techniques-Code of practice for information security controls
- ISO 27017 for Information technology- Security techniques- Code of practice for information security controls based on cloud services
- ISO 27018 for Information technology- Security techniques- Code of practice for protection of Personally Identifiable Information (PII) in public clouds acting as PII processors
- NIST SP 800-53 & 83 for Security and Privacy Controls for Federal Information Systems and Organizations and Guide to Industrial Control Systems (ICS)
- ISA 99/IEC 62443 for Industrial Network and System Security
- ISO 8583 for interfacing with acquired banks

The transmission media and equipment needs to be in redundant configuration so that a single failure does not cause a hazardous failure. The system delays need to be taken into account. The design of System and its Operation & Maintenance shall , in general, comply with recommendation of National Fire Protection Association (NFPA-130 Standards for fixed Guide Way-Transit and Passenger Rail System). This standard specifies fire protection and life safety requirements for underground, surface, and elevated fixed guideway transit and passenger rail systems.

12.6 POWER SUPPLY REQUIREMENT

The power supply has a vital role to play in the functioning of Ticketing and fare collection system. There are a number of computerized/ Electronics equipment's, which are associated with of Ticketing and fare collection system and failure of power supply may lead to failures of these equipment which may cause failure of ticketing system. Ticketing and fare collection system consists of a variety of equipment and gears which require different types of power supply for their functioning.

The Uninterrupted Power Supply (UPS) necessary for the Ticketing and fare collection system. The function of UPS system is to provide a stable and reliable AC and DC power supply for the Ticketing and fare collection system installations against all AC mains variations or even interruptions.

Status Monitoring panel for local control (at Station) shall be provided. The panel consists of status indications and critical alarms of UPS to be provided in local station control room. The monitoring panel shall be of wall mounting type. Indications and alarms are provided on the panel to enable the local controller as well as the central controller to prompt system maintenance staff as and when there is a fault condition and help him to attending fault. Normally the common UPS system should be used for signalling, communication and Ticketing & fare collection system in railway.

12.7 SPACE REQUIREMENT FOR TICKETING AND FARE COLLECTION SYSTEM

The ticketing and fare collection equipment are installed in the every station of SilverLine project. The Ticketing & fare collection system has electronic/computerized components, they shall be equipped with suitable air-conditioning in order to maintain an appropriate temperature and humidity conditions. All the Ticketing and fare collection system equipment are installed at stations and OCC with the following minimum facilities:

- Air-conditioning system
- Fire protection system (as per system required)
- Earthing and Lightning protection system

- Access control (security) system

The space required for Ticketing and fare collection system at station are as:

Table 12-7: Space requirement details

S.No	Name of Room	Minimum Space requirement	Remarks
1.	Ticket office at Main Station	80 Sq. Mtrs	At every station both side of Station/ as per station layout
2.	Automatic gates (AG), TVM	As per station layout	At every station both side/ single side as per station layout
3.	Information Center/EFO	30 Sq. Mtrs	Near to Ticket Office at Station
4.	Cash handling room / AFC Store room (for ticketing room)	30 Sq. Mtrs	Attached /Near to Ticket office at Station

The space for OCC & BCC, the area required shall be as per the final system configuration of the equipment and networking configuration keeping space for further expansion also.

12.8 RECOMMENDATION OF TICKETING & FARE COLLECTION SYSTEM FOR SILVERLINE

The ticketing system shall be computerized system for effective management of the process of reservation, ticket issue and inspection with in a view of improving convenience of users.

The system shall handle all functionalities of the ticketing process, management, access control, fare management, payment, financial requirements, settlement between different registered operators. The system shall generate financial report and management reports. The system shall be responsible for internal and external interface with all ticketing process through gateway and third party. The system software and hardware shall ensure, secured transaction, processing of ticket and payment using appropriate high-level security technology. The system shall ensure the ability to obtain complete and clear data backup and recovery of operation process.

The ticketing & fare collection system shall be connected on a network with a station server controlling the activities of all the local station machines. The station servers will be linked to the central computer situated in OCC through the communication backbone transmission network. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, ticket booking record etc. The central computer system shall be in redundant configuration and located at OCC.

The ticketing and fare collection system shall, as far as possible, operate using high security as per industry standards and shall be a highly reliable, scalable , secure and customer friendly facility. The system security shall include, protection against fraud, theft, falsification of data, false accounting, external threats, denial of service, eavesdropping, loss or corruption of information, masquerading (spoofing) and unauthorized access, etc. The system shall be adhered to industry recognized international and national standards and practices published and maintained by organization such as IEC, ISO, EN and ISI, etc., as applicable.

The ticketing and fare collection system of SilverLine Project in Kerala would comprise of, but not limited to following subsystem for providing state-of-the-art ticketing facility to the passenger:

- Central Computer System (CCS)
- Smart Card (EMV based)
- Mobile Apps/ Mobile Application
- Station Computer System (SCS)
- Ticket Office Machine (TOM)
- Ticket Vending Machine (TVM)/ Self- Service Ticketing KIOSKS
- Mobile Ticket Counter (MTC)
- Portable Processing unit (PPU)
- Automatic Gate (AG)

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 13
TRAIN OPERATION, MAINTENANCE PLAN & SAFETY

13 TRAIN OPERATION PLAN, MAINTENANCE PLAN & SAFETY

13.1 TRAIN OPERATION PLAN

13.1.1 Introduction to Train Operation Plan

This chapter of the report defines an operational specification for the Thiruvananthapuram- Kasaragod SilverLine Corridor based upon the known requirements for infrastructure, rolling stock and the forecast demand and shows the train operation plans which include service frequency, rolling stock requirement, driver requirement, kilometre earnings of rolling stock and timetables for train services etc.

This summary provides background information on the intended service and operations of the proposed Thiruvananthapuram - Kasaragod SilverLine Corridor System to provide sufficient detail for the planning of proposed SilverLine Train operations.

The SilverLine Corridor System will cover 529.450 route-kilometres and service is planned to start in 2025, beginning in Thiruvananthapuram, running through Ernakulam, Thrissur, Kozhikode, Kannur and traveling north to Kasaragod.

Proven train technologies similar to those used in other countries with established high-speed train systems (for example: Japan, France, Germany, Great Britain, Spain, Korea and China) will be used. This technology includes steel-wheel-on-steel-rail, entirely electric power, state-of-the-art safety and signalling systems, and automated train control.

The SilverLine Corridor will operate primarily for the semi high speed passenger services. However it will share the infrastructure for RORO services and tourist trains, other services such as Sleeper services, Aggregator etc. to the extent possible. The route (alignment) will be constructed in either embankment, cut & cover, in a tunnel, or on an elevated/viaduct guideway, depending on the terrain, physical constraints, environmental impacts and community input along each section. The system will predominately be within, or adjacent to, existing rail or highway right-of-way to reduce potential environmental impacts and minimize land acquisition, wherever possible.

13.1.2 Operation Parameters

This section details some of the basic parameters important in the Operation plan.

13.1.2.1 Scheduled Speed

It is the average speed of the train attained in actual revenue service. The average speed is arrived by considering the run time between each station and the station stoppage timings.

13.1.2.2 Headway

It is the time between two trains in revenue operation. The design headway is proposed by the signalling department. In this project, for 200 kmph operation speed, the design head way is minimum 3 minutes. As per the experience of Japanese Shinkansen, they have achieved an operational headway of minimum four minutes.

13.1.2.3 Run Time

It is the total time required for the train to travel from one end of the corridor to the other end of the corridor including the station stoppage time.

13.1.2.4 Reversal Time

It is the total time required for the train to change the direction in the terminal station. It includes the time for point machine operations, train reversal time, train cleaning time, water filling time, pantry filling time, and light maintenance time if required. Subsequent sections cover the details of the reversal time.

13.1.2.5 Dwell Time

It is stoppage time of a train in station. Dwell time is used by the passengers for boarding and de-boarding. It can be used for filling pantry materials also. Dwell time varies based on the passenger number in a station.

13.1.3 SilverLine Corridor Details

The full build system will provide SilverLine train service to passengers from Thiruvananthapuram to Kasaragod with 10 intermediate stops including Kollam, Ernakulam, Kozhikode and Kannur among others. The full build-out of the SilverLine Corridor System is expected to be ready for the operation of revenue service in 2025.

The list of stations identified at this stage is provided in Table 13-1.

Table 13-1:List of Stations

S.NO	STATION NAME	CHAINAGE
1	THIRUVANANTHAPURAM	0
2	KOLLAM	55338
3	CHENGANNUR	102900
4	KOTTAYAM	136108
5	ERNAKULAM	195329
6	KOCHI AIRPORT	212318
7	THRISSUR	259117
8	TIRRUR	320562

S.NO	STATION NAME	CHAINAGE
9	KOZHIKODU	357868
10	KANNUR	446095
11	KASARGOD	529450

A portion of the new dedicated high-speed track may be built early and used for testing and commissioning of the high-speed train sets as they are received from the manufacturer. In addition, early revenue service over a portion (or portions) of the line may be planned, once sufficient train sets have been commissioned and are ready for service. Phased completion of the project may be undertaken which shall be finalised during the execution stage.

The corridor is proposed to be designed to be operable as a permanent, stand-alone system. While estimated to be operational by 2025, the section may be opened in stages and the extensions to operational part of line could be added to the network subsequently as corresponding sections are completed.

The entire corridor is provided with horizontal curve radius of 1850 m except in some station approaches. Hence an operational speed of 200 kmph is achievable in all sections of the corridor. All the stations are provided with loop lines for the SilverLine Corridor trains and RORO trains for managing the operational flexibility. Major stations such as Thiruvananthapuram, Ernakulam, Thrissur, Kozhikode, Kannur and Kasaragod are provided with cross overs to manage the long loop and short loop operations of the SilverLine trains.

13.1.4 Rolling Stock Details

Summary details of different types of Rolling Stock used in the corridor is listed in this section.

13.1.4.1 SilverLine Rolling Stock Details

EMU type Rolling Stock is proposed for the SilverLine Corridor. The summary of the proposed Rolling Stock is listed in Table 13-2.

Table 13-2:Summary of Rolling Stock

Details	Requirements	Remarks
Track Gauge	1435 mm	Standard Gauge
Maximum Width of Car body	3.4 Meter	For maximising the passenger/floor area

Details	Requirements	Remarks
Maximum Length over coupler of Car body	25 Meter	Optimised considering the platform length and passenger carrying requirement
Nominal Height of the Car body	4.5 Meter	Optimised considering the construction gauge and the tunnel height
Train Configuration	9 Car DMC-TC-MC-MC-TC-MC-MC-TC-DMC 12 Car DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC 15 Car DMC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-MC-MC-TC-DMC	DMC- Driving Motor Car, TC- Trailer Car
Coach Type	Executive Coach with 2+2 seating Normal Coach with 2+3 seating Normal Coach with pantry and 2+3 seating Normal Coach with PRM facility and 2+3 seating	
Seating Capacity	Average Seating Capacity- 75	
Doors External	2 Numbers on each side of the Car	In Driving Car only one door per side of the car for passenger movement and separate door for driver entry into the driving cab
Doors Internal	One Number on each end of the Car	In Driving Car only one door on extreme end of the car for passenger movement.
Luggage Space	One at each car	One at each car for big sized luggage and side-line luggage racks for small/medium size luggage
Maximum Speed	Operational-200 kmph Design- 220 kmph	

Details	Requirements	Remarks
Initial Acceleration	Not less than 0.6 m/sec^2	At 200 KMH residual acceleration shall be more than 0.1 m/sec^2.
Average Deceleration	Not less than 0.6 m/sec^2	Emergency Brake Deceleration- Maximum 1.3 m/sec^2
Axle Load	16 Ton	

13.1.4.2 RORO Rolling Stock Details

The RORO trains are formed by two locomotives and 40 wagons coupled together. Two locomotives are required for hauling the train in steep gradient (1 in 60) and to maintain 120 kmph. The two locomotives shall be operated in synchronous way during traction and braking. The traction is achieved by the motors provided on the axles of the locos. In Locomotive the braking shall be blended braking with predominant usage of regenerative braking and supplementary usage of pneumatic braking. In the wagons the braking shall be achieved using pneumatic brakes only. The brake rate shall be synchronised in the whole train by the brake control electronics.

The trucks on the wagons shall be loaded either from the side of the wagons or from the end of the wagons (in Konkan railway, end loading is performed, however during discussions, it is proposed to use side loading in SilverLine even though there is no reference for side loading). For performing side and end loading of the truck to the wagons, the necessary infrastructures such as platforms and ramps are proposed to be provided.

The height of the truck to be loaded on the wagon is limited to 3400 mm in order to respect the structure gauge dimensions. The maximum height of truck loaded on wagon from rail level shall be 4500 mm. The trucks shall be weighed, and height checking shall be done before loading to the wagon. The details of the RORO Rolling Stock is shown in Table 13-3.

Table 13-3:Summary of RORO Rolling Stock

Details	Requirements	Remarks
Maximum Speed	Operational-120 kmph Design- 130 kmph	
Initial Acceleration	Not less than 0.2 m/sec^2	
Average Deceleration	Not less than 0.6 m/sec^2	Emergency Brake Deceleration- Maximum 1.3 m/sec^2

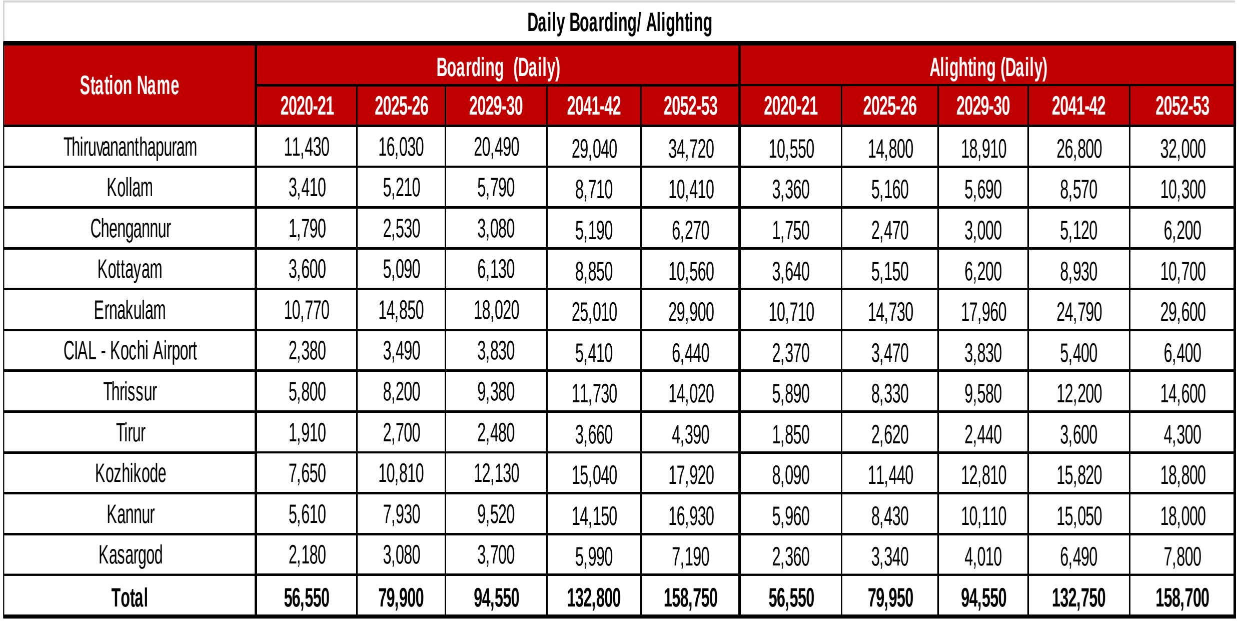
Details	Requirements	Remarks
Axle Load	22.5 Ton	
Train Length	Maximum 700 Meter	
Service Braking Distance	Less than 3000 M	
Emergency Braking Distance	Less than 1300 M	

13.1.5 Demand Forecast

Detailed traffic survey is conducted as part of the preparation of the DPR of SilverLine corridor. The results of the traffic survey are summarised in this section.

13.1.5.1 Daily Traffic Load

The daily passenger traffic load in the entire SilverLine corridor as per the traffic survey results is listed in Figure 13-1.



Daily Boarding/ Alighting

Station Name	Boarding (Daily)					Alighting (Daily)				
	2020-21	2025-26	2029-30	2041-42	2052-53	2020-21	2025-26	2029-30	2041-42	2052-53
Thiruvananthapuram	11,430	16,030	20,490	29,040	34,720	10,550	14,800	18,910	26,800	32,000
Kollam	3,410	5,210	5,790	8,710	10,410	3,360	5,160	5,690	8,570	10,300
Chengannur	1,790	2,530	3,080	5,190	6,270	1,750	2,470	3,000	5,120	6,200
Kottayam	3,600	5,090	6,130	8,850	10,560	3,640	5,150	6,200	8,930	10,700
Ernakulam	10,770	14,850	18,020	25,010	29,900	10,710	14,730	17,960	24,790	29,600
CIAL - Kochi Airport	2,380	3,490	3,830	5,410	6,440	2,370	3,470	3,830	5,400	6,400
Thrissur	5,800	8,200	9,380	11,730	14,020	5,890	8,330	9,580	12,200	14,600
Tirur	1,910	2,700	2,480	3,660	4,390	1,850	2,620	2,440	3,600	4,300
Kozhikode	7,650	10,810	12,130	15,040	17,920	8,090	11,440	12,810	15,820	18,800
Kannur	5,610	7,930	9,520	14,150	16,930	5,960	8,430	10,110	15,050	18,000
Kasargod	2,180	3,080	3,700	5,990	7,190	2,360	3,340	4,010	6,490	7,800
Total	**56,550**	**79,900**	**94,550**	**132,800**	**158,750**	**56,550**	**79,950**	**94,550**	**132,750**	**158,700**

Figure 13-1: Daily Ridership

13.1.5.2 PHPDT

The sectional Peak Hour Peak Direction Traffic (PHPDT) is also provided as part of the traffic studies. It is shown in Figure 13-2.

Peak Hour Section Load

Station Name	Forward				Reverse			
	2025-26	2029-30	2041-42	2052-53	2025-26	2029-30	2041-42	2052-53
Thiruvananthapuram	0	0	0	0	990	1,270	1,800	2,150
Kollam	1,160	1,480	2,090	2,500	1,110	1,440	2,050	2,450
Chengannur	1,350	1,750	2,490	2,970	1,300	1,700	2,360	2,830
Kottayam	1,240	1,610	2,240	2,680	1,090	1,420	2,000	2,390
Ernakulam	1,320	1,720	2,410	2,880	1,330	1,640	2,430	2,910
CIAL - Kochi Airport	1,440	1,780	2,640	3,160	1,350	1,650	2,440	2,920
Thrissur	1,360	1,660	2,460	2,950	1,140	1,360	1,860	2,220
Tirur	1,080	1,290	1,760	2,100	1,070	1,220	1,670	2,000
Kozhikode	1,270	1,450	1,980	2,370	640	760	1,170	1,400
Kannur	730	870	1,340	1,600	230	270	440	530
Kasargod	270	330	530	630	0	0	0	0
Maximum Section Load (PHPDT)	**1,440**	**1,780**	**2,640**	**3,160**	**1,350**	**1,700**	**2,440**	**2,920**

Figure 13-2: PHPDT

**PHPDT- Peak Hour Peak Direction Traffic*

13.1.5.3 Daily Section Load

Similarly, the maximum passenger load on each section provided in between 11 Stations are provided in Figure 13-3.

Daily Ridership Section Load

Station Name	Forward					Reverse				
	2020-21	2025-26	2029-30	2041-42	2052-53	2020-21	2025-26	2029-30	2041-42	2052-53
Thiruvananthapuram	0	0	0	0	0	10,550	14,800	18,910	26,800	32,050
Kollam	11,400	16,030	20,490	29,040	34,720	11,230	15,380	20,050	28,420	33,970
Chengannur	12,170	16,660	21,720	30,790	36,800	11,770	16,140	21,010	29,230	34,970
Kottayam	12,750	17,480	22,760	31,670	37,880	11,270	15,440	20,160	28,260	33,790
Ernakulam	12,210	16,730	21,830	30,610	36,600	12,010	16,860	20,890	30,940	37,010
CIAL - Kochi Airport	13,010	18,270	22,630	33,520	40,090	12,120	17,130	20,940	31,030	37,090
Thrissur	13,128	18,560	22,680	33,620	40,180	11,030	15,590	18,560	25,320	30,260
Tirur	11,950	16,890	20,110	27,430	32,780	11,770	16,640	19,050	26,030	31,080
Kozhikode	12,750	18,020	20,640	28,200	33,660	6,390	9,040	10,820	16,690	19,970
Kannur	6,927	9,790	11,720	18,080	21,640	2,180	3,080	3,700	5,990	7,190
Kasargod	2,360	3,340	4,010	6,490	7,790	0	0	0	0	0
Total	**13,128**	**18,560**	**22,760**	**33,620**	**40,180**	**12,120**	**17,130**	**21,010**	**31,030**	**37,090**

Figure 13-3: Daily Sectional Load

13.1.5.4 RORO Traffic Load

The RORO truck traffic requirement is estimated as 445 trucks per day, arrived after the detailed traffic analysis, to be carried in the Silver Line corridor.

13.1.6 SilverLine Train Travelling Time

The travelling time or run time of SilverLine train is simulated considering two minutes dwell time at all intermediate stations. Most of the track curves are designed for the running speed of 200 kmph (Curve radius 1850 m). However in some exceptional cases curves are provided with radius 650 m near the approaches of some stations where the maximum operating speed is 115 kmph. The travel time for a SilverLine train from Thiruvananthapuram to Kasaragod is listed in Table 13-4:

Table 13-4:Run Time SilverLine Trains

S.NO	STATION NAME	CHAINAGE	RUN TIME
1	THIRUVANANTHAPURAM	0	0:00
2	KOLLAM	55338	0:24
3	CHENGANNUR	102900	0:46
4	KOTTAYAM	136108	1:01
5	ERNAKULAM	195329	1:27
6	KOCHI AIRPORT	212318	1:36
7	THRISSUR	259117	1:57
8	TIRRUR	320562	2:24
9	KOZHIKODU	357868	2:42
10	KANNUR	446095	3:20
11	KASARGOD	529450	3:56

Similarly, the run time of RORO considering no stoppage in between stations is shown in Table 13-5.

Table 13-5:Run Time- RORO Trains

S.NO	STATION NAME	CHAINAGE	RUN TIME
1	THIRUVANANTHAPURAM	0	0:00
2	KOLLAM	55338	0:37

S.NO	STATION NAME	CHAINAGE	RUN TIME
3	CHENGANNUR	102900	1:10
4	KOTTAYAM	136108	1:32
5	ERNAKULAM	195329	2:12
6	KOCHI AIRPORT	212318	2:24
7	THRISSUR	259117	2:56
8	TIRRUR	320562	3:38
9	KOZHIKODU	357868	4:03
10	KANNUR	446095	5:04
11	KASARGOD	529450	6:01

13.1.7 Operation Plan

13.1.7.1 Operation Plan Introduction

Concept level rail operations and service plan has been developed to serve several purposes:

- Confirm the level of service assumptions (travel times and service frequencies between station pairs) used to develop the estimates of system ridership and revenue
- Validate the operational feasibility of the desired level of service at a conceptual level
- Identify operable patterns of train service, particularly the general requirements for non-stop or limited-stop trains to pass slower trains that need to make a greater number of (local) stops along the route (i.e., the locations and frequencies of occurrence of these “overtakes” at various times of day)
- Provide a basis for an order of magnitude estimate of the number of train sets and overall rolling stock fleet requirements for the full corridor
- Provide a basis for estimating platform track and storage track capacity to support operations at the end and intermediate terminal stations
- Provide a basis for sizing train storage and maintenance facilities throughout the SilverLine System.
- Provide a basis for planning passenger-handling operations at SilverLine stations, which can be used to help size and configure station facilities.

In the proposed SilverLine Corridor, the following types of rail operations are to be performed.

1. SilverLine trains service- It will be running between the 11 SilverLine stations. The operation pattern is detailed in the subsequent sections based on the traffic demand.
2. RORO Services- To utilise the infrastructure to its full extent, ‘Roll on Roll off’ or piggyback train running is proposed. The loco hauled trains will carry trucks in the same corridor during the lean hours in daytime and during night-time.
3. Tourist Train Services- Tourist trains with special facilities for the passengers such as dining, lodging etc. are to be run in the SilverLine corridor. The frequency of the tourist services shall be finalised during the design stage of the project.

13.1.7.2 SilverLine Operation Plan

The objective of SilverLine Operation is listed below:

- To reduce the travel time between Thiruvananthapuram to Kasaragod. Currently the travel time using the existing Indian Railway is 10-12 Hours. The SilverLine Train Operation will reduce the travel time from Thiruvananthapuram to Kasaragod to four hours.
- Over the maximum possible length, the operational speed of 200 kmph shall be achieved. The acceleration and deceleration values and other infrastructure parameter is selected such a way that in most of the sections the SilverLine train will run in 200 kmph so that the travel time is reduced.
- To adopt the average passenger load factor of 75% for setting operation plan. An average passenger load factor should be 75%, taking into the fluctuation of the number of passengers.
- To operate full loop operation and short loop operation to manage the traffic demand efficiently.
- To start the revenue operation with 9 Car configuration in 2025 and subsequently increase the number of cars as per the traffic demand arises with 12 and 15 Car configuration.
- Provide room for other types of Rolling Stock operations- It is planned to run RORO services in between the SilverLine operations. However, the precedence of operation will be given to the SilverLine passenger services.

13.1.7.2.1 Operation Loops

Based on the forecasted traffic demand, it is proposed to run full section loop and short loops to manage the traffic demand efficiently. The normal operation hours of the SilverLine Service are from 05:00 hrs to 23:00 Hrs. The following operation loops are proposed for SilverLine corridor considering an average passenger load factor of 75%. These loops are arrived based on the maximum traffic figures estimated in the SilverLine corridor. The loops are to be managed as per the traffic demand of the different time of day. RORO are to be run during day time in off peak hours and during night after stopping the passenger services.

Based on the section wise traffic demand arrived on study, the number of services required is worked out in different sections/loops.

Table 13-6:Operation Loops

Loop Name	Loop Details
Loop A	From Thiruvananthapuram to Kozhikode
Loop B	From Thiruvananthapuram to Kannur
Loop C	From Thiruvananthapuram to Kasaragod

13.1.7.2.2 Train Seating Capacity

For calculation purpose an average seating of 75 seats per car is considered in the operation plan. The train seating capacity is listed in the Table 13-7:

Table 13-7:Seating Capacity

Train Configuration	Seat Capacity
9- Car	675
12- Car	900
15- Car	1125

13.1.7.2.3 Horizon Year 2025-2026

It is planned to begin the revenue service of the SilverLine corridor in 2025-2026. Based on the traffic figures and the headway to be managed, it is proposed to use train with 9 Car configuration for the initial services. The abstract of the traffic figures for the year 2025-2026 is shown in Table 13-8.

Table 13-8:Traffic Figures-2025-2026

From	To	Ridership	PHPDT	Distance-KM
Thiruvananthapuram	Kozhikode	18560	1440	358
Thiruvananthapuram	Kannur	9790	730	446
Thiruvananthapuram	Kasaragod	3340	270	529

Based on the above traffic figures, three operation loops are proposed in the corridor. In this operation loops trains will stop in all SilverLine stations within the operation loop. The trains will be reversed in the terminal stations of the operation loop.

- Loop A - In between Thiruvananthapuram and Kozhikode

- Loop B - In between Thiruvananthapuram and Kannur
- Loop C- In between Thiruvananthapuram and Kasaragod

Note- In Loop C, even though the traffic figures low, it is decided to run one trip per direction in each hour considering the passenger convenience.

The total number of trips to be conducted with 9 Car train is calculated as shown in Table 13-9.

Table 13-9:Number of Trips-2025-2026

Loops	Terminal Station	Number of Trips in each direction	Trains Per Hour (Maximum)
Loop A	Thiruvananthapuram - Kozhikode	37	3
Loop B	Thiruvananthapuram - Kannur	20	
Loop C	Thiruvananthapuram - Kasaragod	18	

Figure 13-4 shows the operation plan for the horizon year 2025-2026. As per the above sheet, 37 trips in each direction to be done in Loop A, 20 Trips in each direction to be done in Loop B and 18 Trips in each direction to be done in Loop C.

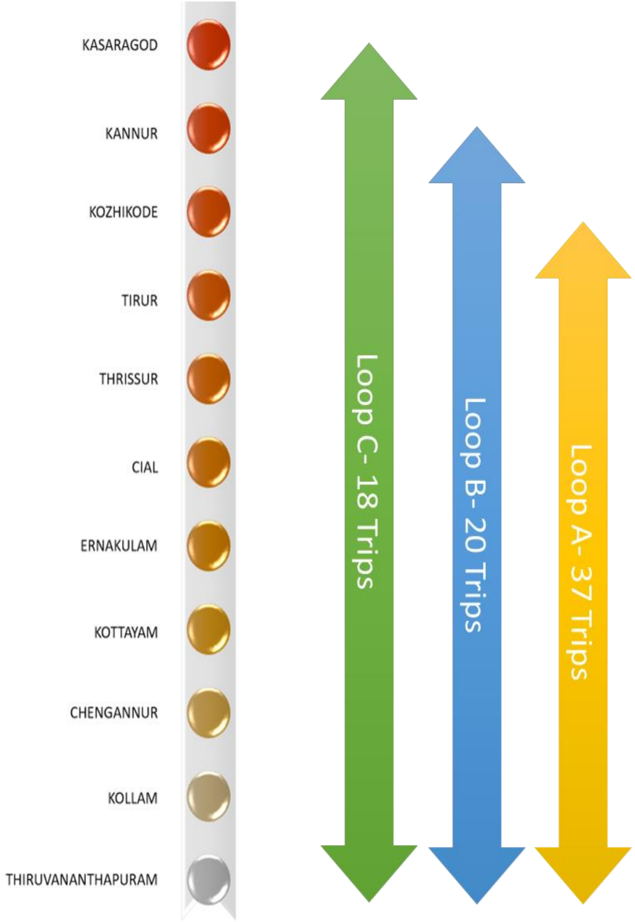


Figure 13-4: Operation Loops-2025-2026

13.1.7.2.4 Horizon Year 2029-2030

Based on the traffic figures and the headway to be managed, it is proposed to use train with 9 Car configuration for the 2029-2030 horizon year operation. The abstract of the traffic figures for the year 2029-2030 is shown in Table 13-10.

Table 13-10:Traffic Figures-2029-2030

From	To	Ridership	PHPDT	Distance-KM
Thiruvananthapuram	Kozhikode	22760	1780	358
Thiruvananthapuram	Kannur	11720	870	446
Thiruvananthapuram	Kasaragod	4010	330	529

Based on the above traffic figures, three operation loops are proposed in the corridor. In this operation loops trains will stop in all SilverLine stations within the operation loop. The trains will be reversed in the terminal stations of the operation loop.

- Loop A - In between Thiruvananthapuram and Kozhikode
- Loop B - In between Thiruvananthapuram and Kannur
- Loop C- In between Thiruvananthapuram and Kasaragod

Note- In Loop C, even though the traffic figures low, it is decided to run one trip per direction in each hour considering the passenger convenience.

The total number of trips to be conducted with 9 Car train is calculated as shown in Table 13-11.

Table 13-11:Number of Trips-2029-2030

Loops	Terminal Station	Number of Trips in each direction	Trains Per Hour (Maximum)
Loop A	Thiruvananthapuram - Kozhikode	45	4
Loop B	Thiruvananthapuram - Kannur	24	
Loop C	Thiruvananthapuram - Kasaragod	18	

Figure 13-5 shows the operation plan for the horizon year 2029-2030. As per the above sheet, 45 trips in each direction to be done in Loop A, 24 Trips in each direction to be done in Loop B and 18 Trips in each direction to be done in Loop C.

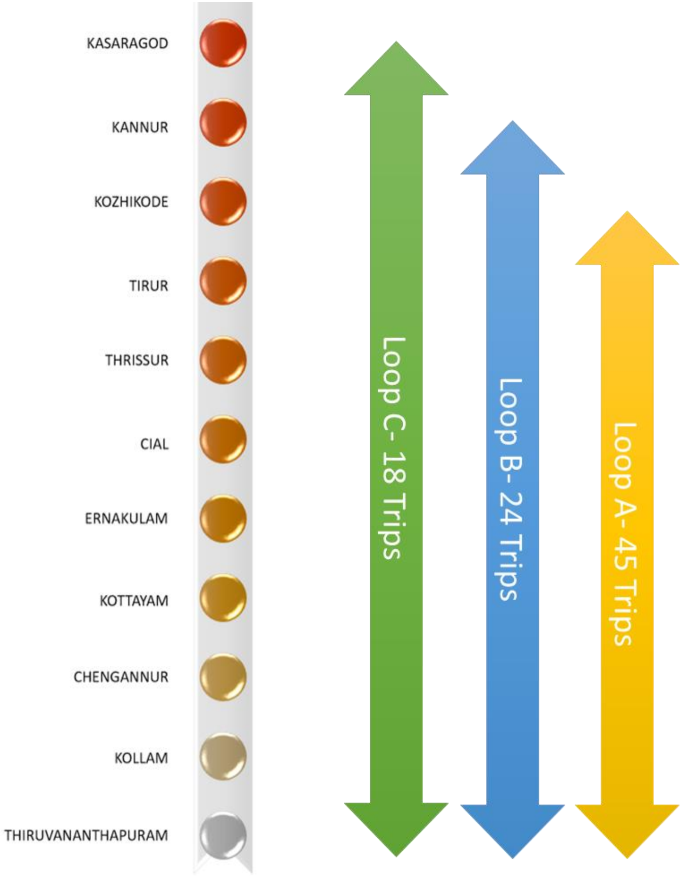


Figure 13-5: Operation Loops-2029-2030

13.1.7.2.5 Horizon Year 2041-2042

Based on the traffic figures and the headway to be managed, it is proposed to use train with 9 Car configuration & 15 Car Configuration for the 2041-2042 horizon year operation. The abstract of the traffic figures for the year 2041-2042 is shown in Table 13-12.

Table 13-12:Traffic Figures-2041-2042

From	To	Ridership	PHPDT	Distance-KM
Thiruvananthapuram	Kozhikode	33620	2640	358
Thiruvananthapuram	Kannur	18080	1340	446
Thiruvananthapuram	Kasaragod	6490	530	529

Based on the above traffic figures, three operation loops are proposed in the corridor. In this operation loops trains will stop in all SilverLine stations within the operation loop. The trains will be reversed in the terminal stations of the operation loop.

- Loop A - In between Thiruvananthapuram and Kozhikode
- Loop B - In between Thiruvananthapuram and Kannur
- Loop C- In between Thiruvananthapuram and Kasaragod

The total number of trips to be conducted with 9 Car train & 15 Car train is calculated as shown in Table 13-13.

Table 13-13: Number of Trips-2041-2042

Loops	Terminal Station	Number of Trips in each direction	Trains Per Hour (Maximum)
Loop A	Thiruvananthapuram - Kozhikode	58	6
Loop B	Thiruvananthapuram - Kannur	36	
Loop C	Thiruvananthapuram - Kasaragod	18	

Figure 13-6 shows the operation plan for the horizon year 2041-2042. As per the above sheet, 58 trips in each direction to be done in Loop A, 36 Trips in each direction to be done in Loop B and 18 Trips in each direction to be done in Loop C.

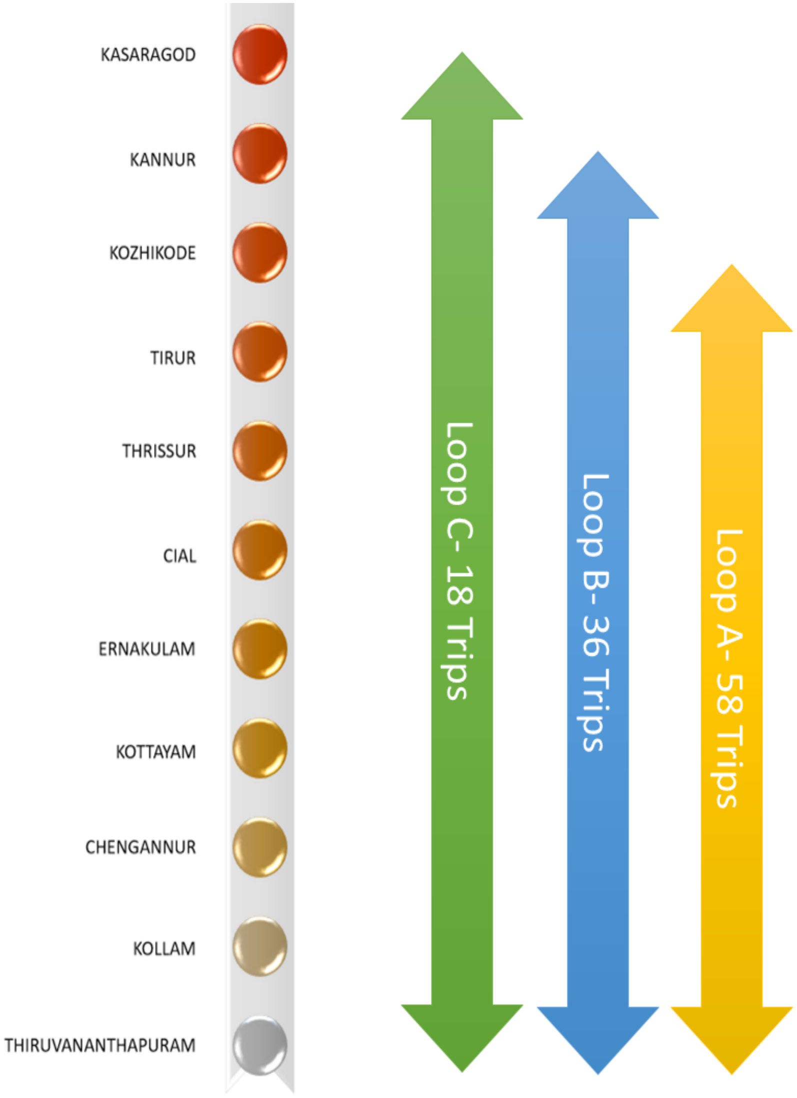


Figure 13-6: Operation Loops-2041-2042

13.1.7.2.6 Horizon Year 2052-2053

Based on the traffic figures and the headway to be managed, it is proposed to use train with 9 Car configuration & 15 Car configuration for the 2052-2053 horizon year operation. The abstract of the traffic figures for the year 2052-2053 is shown in Table 13-14.

Table 13-14:Traffic Figures-2052-2053

From	To	Ridership	PHPDT	Distance-KM
Thiruvananthapuram	Kozhikode	40180	3160	358
Thiruvananthapuram	Kannur	21640	1600	446
Thiruvananthapuram	Kasaragod	7790	630	529

Based on the above traffic figures, three operation loops are proposed in the corridor. In this operation loops trains will stop in all SilverLine stations within the operation loop. The trains will be reversed in the terminal stations of the operation loop.

- Loop A - In between Thiruvananthapuram and Kozhikode
- Loop B - In between Thiruvananthapuram and Kannur
- Loop C- In between Thiruvananthapuram and Kasaragod

The total number of trips to be conducted with 9 Car train & 15 Car train is calculated as shown in Table 13-15.

Table 13-15:Number of Trips-2052-2053

Loops	Terminal Station	Number of Trips in each direction	Trains Per Hour (Maximum)
Loop A	Thiruvananthapuram - Kozhikode	65	6
Loop B	Thiruvananthapuram - Kannur	43	
Loop C	Thiruvananthapuram - Kasaragod	18	

Figure 13-7 shows the operation plan for the horizon year 2052-2053. As per the above sheet, 65 trips in each direction to be done in Loop A, 43 Trips in each direction to be done in Loop B and 18 Trips in each direction to be done in Loop C.

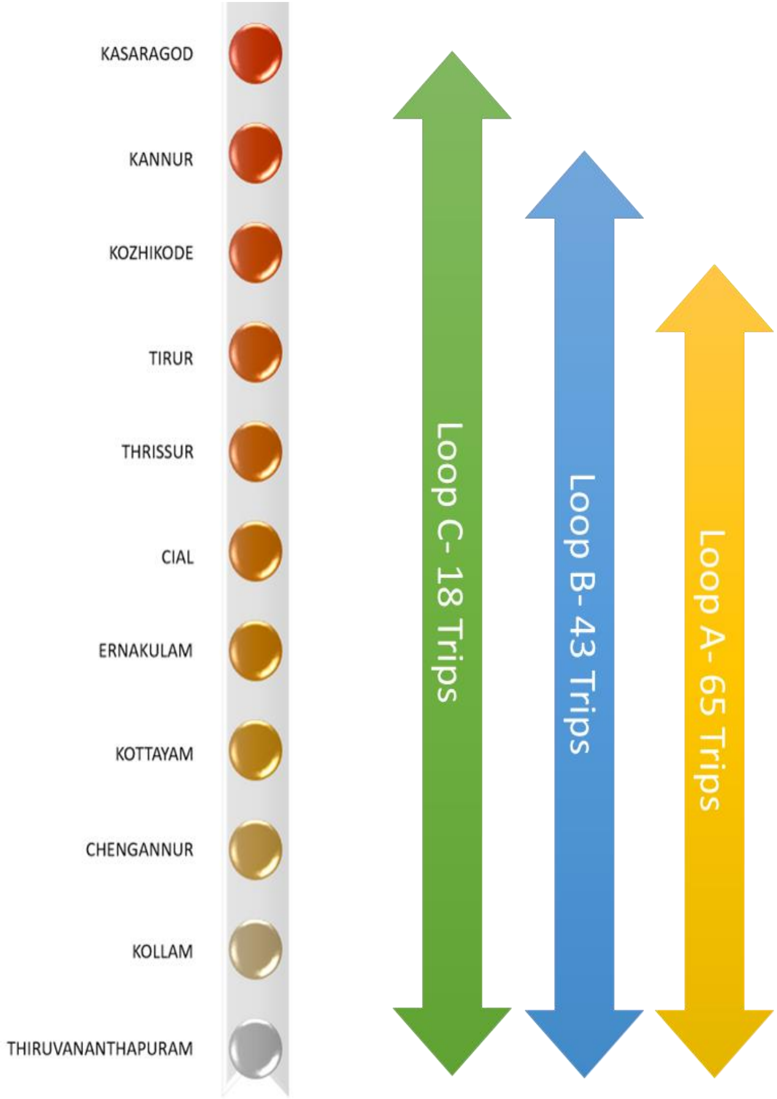


Figure 13-7: Operation Loops-2052-2053

13.1.7.2.7 Summary of SilverLine Operation Plan

The operation plan of SilverLine train is summarised here. The headway of the corridor on different horizon year also mentioned in Table 13-16.

Table 13-16: SilverLine Operation plan summary

Items	2025-26	2029-30	2041-42	2052-53
Train Configuration	9 Car	9 Car	9 Car + 15 Car	9 Car + 15 Car
Train Capacity	675	675	675 & 1125	675 & 1125

Items	2025-26	2029-30	2041-42	2052-53
Traffic Volume (per day per direction)	18560	22760	33620	40180
Number of Trips between Thiruvananthapuram to Kasaragod (Per day per direction)	18	18	18	18
Number of Trips between Thiruvananthapuram to Kannur (Per day per direction)	20	24	36	43
Number of Trips between Thiruvananthapuram to Kozhikode (Per day per direction)	37	45	58	65
Number of Trains (in a peak hour per direction)	3	4	6	6
Headway (minimum in the line)	20 Minutes	15 Minutes	10 Minutes	10 Minutes

13.1.7.3 RORO Operation Plan

The RORO services will also share the SilverLine corridor for carrying the trucks from different stations. The RORO trains are hauled by locomotives with a maximum operational speed of 120 kmph. The acceleration and deceleration of RORO trains are much lower compared to SilverLine trains. Hence it requires more time for running and shunting the RORO trains. This aspect is considered while deriving the operation plan for RORO trains. As per the guidance from K-Rail, five stations are RORO operating stations which are provided with RORO loading and unloading facilities ie. Thiruvananthapuram, Kollam, Ernakulam, Thrissur and Kasaragod.

Considering the operational flexibility and operation time, the RORO trains are proposed to run route bound, i.e. its starting and destination is fixed, and no loading or unloading of trucks is permitted in between stations. The RORO trains will not stop in any stations other than its destination and it will halt in SilverLine stations for providing precedence to high speed trains if required.

The RORO trains are to be run in between the SilverLine Trains during daytime and RORO trains can run without any limitation during night-time respecting the maintenance slots. The RORO services will be put in halt during the peak hours where the corridor headway is less, and RORO services will continue during the non-peak hours and night-time. However due to its low average speed and lower acceleration and deceleration, it is not proposed to run the RORO train in between SilverLine Trains, if the corridor headway is less than 30 minutes (if we run RORO train with corridor headway less than 30 minutes, it need to halt in many locations and the run time from start to destination may exceed more than 10 hours in one direction).

It is planned to load the trucks on the RORO from side of the wagon as well as the end of the wagon. It is anticipated to complete the loading of the 40 trucks to the train within 30 minutes.

The trucks are to be weighed and parked in the parking lot before loading to the wagon. Once the train is arrived, the bridge plates are set in between wagon and the loading platform. The trucks are loaded from side of the train and end of the train after clearing the height gauge. Same process is followed for unloading also. No reverse movement of the trucks are allowed during the loading or unloading. Latching and locking mechanism are to be provided in the wagon to properly fix the trucks above wagon. Proper earthing of the trucks is to be ensured after loading the truck on the wagon.

After the traffic analysis, it is expected to carry approximately 450-480 trucks throughout the corridor per day. To carry 480 trucks in the corridor, there shall be 6 RORO trips in each direction per day considering 40 wagons per RORO train. It is proposed to run 3 trips during daytime in the non-peak hours and 3 trips in the night-time in each direction.

RORO operation plan is summarized below.

- Number of Wagons in a train-40
- Number of Trains- 6
- Total number of trucks to be carried in a day- 480
- Number of round trips in day- 6 (3 trips during day off peak time and 3 trips during night)

In future, if the headway of the corridor decreases because of increased traffic, the RORO services can be limited to night-time or can be tapered down in order to maintain operational performance of the SilverLine Train services.

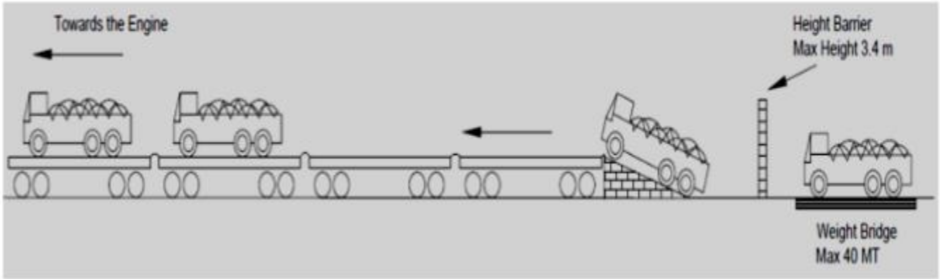


Figure 13-8: Typical RORO Loading

13.1.8 Mileage Details

The km gained by the SilverLine trains during service as per the number of trips in a day is listed in Table 13-17.

Table 13-17: Mileage Details of SilverLine Trains

Year	Train Configuration	Number of Trips (per day per direction)			KM Gained (per day)			Total Km Gained (per day)
		Loop A	Loop B	Loop C	Loop A	Loop B	Loop C	
2025-26	9 Car	37	20	18	12172	1784	19044	33000
2029-30	9 Car	45	24	18	15036	5352	19044	39432
2041-42	9 Car & 15 Car	58	36	18	15752	16056	19044	50852
2052-53	9 Car & 15 Car	65	43	18	15752	22300	19044	57096

The km gained by the RORO trains during service as per the number of trips in a day is listed in the Table 13-18.

Table 13-18: Mileage Details of RORO Train

Year	Train Configuration	Number of Trips (per day per direction)	KM Gained (per day)
2025-26	1L-40W-1L	6	6348
2029-30	1L-40W-1L	6	6348
2041-42	1L-40W-1L	6	6348
2052-53	1L-40W-1L	6	6348

13.1.9 Rolling Stock Requirement

Based on above number of trips and km gained, the fleet requirement for SilverLine service and RORO service is listed in the below Table 13-19 & Table 13-20. Based on the international practices, the maintenance spare is considered as 10% of the bare minimum required fleets and the operation reserve is considered as 5% of the bare minimum required fleets for the passenger operations.

13.1.9.1 SilverLine Rolling Stock Requirement

The fleet requirement for the SilverLine service is projected in the Table 13-19 considering per train per day running km as 1,500 km:

Table 13-19: Rolling Stock Requirement SilverLine

Year		2025-2026	2029-2030	2041-2042		2052-2053	
Rolling Stock Configuration		9 Car	9 Car	9 Car	15 Car	9 Car	15 Car
Bare Minimum RS Required in each loop	Loop A	9	11	4	7	0	11
	Loop B	2	4	11	0	15	0
	Loop C	13	13	13	0	13	0
Bare Minimum RS Required		24	28	28	7	28	11
Maintenance Reserve		3	3	3	1	3	2
Operation Reserve		2	2	2		2	
Total Rolling Stock Required		29	33	41		46	
Number of Cars		261	297	417		492	

13.1.9.2 RORO Rolling Stock Requirement

RORO train needs to carry approximately 480 trucks in day. Accordingly, the number of RORO train requirement is derived as per Table 13-20.

Table 13-20: Rolling Stock Requirement RORO

Year	2025-26	2029-30	2041-42	2052-53
RORO Train Configuration	1Loco-40 Wagon-1Loco	1Loco-40 Wagon-1Loco	1Loco-40 Wagon-1Loco	1Loco-40 Wagon-1Loco
Number of Trips in one direction per day	6	6	6	6
RORO Train Required	6	6	6	6

Year	2025-26	2029-30	2041-42	2052-53
Number of Locomotives	12	12	12	12
Number of Wagons	240	240	240	240

13.1.10 Rolling Stock Storage

The Rolling Stock shall be stabled in Depots as well as the Mainline. Most of the trains will be stabled in Depots. However, for the flexibility of operation and to avoid the empty running of trains, stabling facilities are proposed in the main line also. These stabling lines in the main line can be used to stable the train during non-peak hours and night-time.

The SilverLine trains require 400 m length stabling lines considering 15 car configuration and RORO trains require 700 m length stabling lines considering 2 Loco and 40 Wagons. With the above assumption, the following storage arrangement for SilverLine trains and RORO trains are derived.

Table 13-21: Storage of Rolling Stock

Rolling Stock Track Lines Requirement															
Year	TS Nos	SBL	Total Required	KLM Depot	KGQ Depot	TVM	KLM	CNGR	KTM	EKM	TSR	TIR	KKD	KNR	KGD
2025-2026	SHSR-29*9 RORO-6	SBL Normal (400 M)	28	12	6	2				2	2		2	2	
		SBL RORO (700 M)	7	2		1	1			1	1				1
		IBL-400 M	6	4	2										
		WBL-400 M	5	5											
2029-2030	SHSR-33*9 RORO-6	SBL Normal (400 M)	32	12	7	2				3	4		2	2	
		SBL RORO (700 M)	7	2		1				1	1				1
		IBL-400 M	7	4	3										
		WBL-400 M	5	5											
2041-2042	SHSR-33*9 & 8*15 RORO-6	SBL Normal (400 M)	40	12	14	3				3	4		2	2	
		SBL RORO (700 M)	7	2		1				1	1				1
		IBL-400 M	8	4	4										
		WBL-400 M	6	6											
2052-2053	SHSR-33*9 & 13*15 RORO-6	SBL Normal (400 M)	45	12	15	4				4	5		3	2	
		SBL RORO (700 M)	7	2		1				1	1				1
		IBL-400 M	9	5	4										
		WBL-400 M	6	6											

**IBL- Inspection Bay Line, SBL- Stabling Bay Line, WBL- Workshop Bay Line*

13.1.11 Service Frequency

The service frequency or headway of the Thiruvananthapuram - Kasaragod SilverLine corridor is not only determined by the SilverLine trains, but also the RORO trains. The overall service frequency required for a particular train type and formation is given by dividing the PHPDT by the capacity of the train with load factor. The service frequency details of the SilverLine trains are detailed in the below section.

The service frequency of SilverLine trains for different horizon year is shown in Table 13-22.

Table 13-22: SilverLine Service Frequency

Year	2025-2026	2029-2030	2041-2042	2052-2053
Train Configuration	9-Car	9-Car	9-Car & 15-Car	9-Car & 15-Car
Maximum Service Frequency in the corridor	3 TPH	4 TPH	6 TPH	6 TPH
Headway	20 Minutes	15 Minutes	10 Minutes	10 Minutes

The RORO operations will be conducted during non-peak hours and night-time only. Hence the minimum corridor headway is determined by the combined operation of SilverLine trains and RORO trains. It is referenced that Japanese Shinkansen has run high speed trains with headway as low as four minutes. Considering the above operation plan, the SilverLine corridor headway may go as low as 10 minutes practically.

13.1.12 Dwell Time

This section covers the details of dwell time of different type of trains and the train reversal time required in terminal stations.

Demand data identifies the number of boarding and alighting passengers forecast at each station per day, split by direction. For each direction the sum of these values gives the total number of passengers using the station in a day and peak hour factor of these values gives the number of passengers using each station in the peak hour.

The train frequency at each station is known as is the number of doors in each train, therefore the number of passengers using each door can be calculated.

There are four elements to dwell time:

- Door opening time
- Passengers alighting
- Passengers boarding
- Door closing time

13.1.12.1 Dwell Time Results

The dwell time of SilverLine train is derived for different horizon year considering the demand forecast and the car configuration at respective horizon year. In different high speed trains, the dwell time varies from 1 minute to 5 minutes based on the traffic conditions of stations. In Japanese Shinkansen, dwell time in minor stations is 1 minute and that of major stations is 2 minutes. In France SNCF provides 2 minutes dwell time in normal stations.

From the analysis and considering margin for seasonal variation it is proposed to use, the dwell time as 2 minutes in all stations for all horizon year.

13.1.12.2 Train Reversal Time

Because the terminals are stub-ended, all SilverLine trains will change directions (turnaround with rear end of the arriving train becoming the front end of the departing train) at terminal stations. Three types of train turnaround will occur in terminal stations:

- Revenue to Non-Revenue: Revenue trains (with passengers) arrive, with the equipment turning around and going to the rail depot for storage or servicing, without passengers
- Non-Revenue to Revenue: Trains enter the terminal from the rail depot (without passengers), departing passengers board (the train), and the train departs as a revenue train (with passengers)
- Revenue to Revenue: Revenue trains (with passengers) arrive and passengers unload, the train would park at the platform while it is inspected, cleaned and restocked with bathroom and food service supplies, departing passengers board the train, and the train departs as a revenue train (with passengers).

Estimating the time required to carry out the various terminal turnaround train servicing and passenger processing functions, and identifying which functions can proceed in parallel with each other and which depend upon the prior completion of other activities, allows definition of a “critical path” of activities that governs the minimum time necessary between an inbound train arrival and the subsequent outbound train departure. The required sequence of steps that must be followed for four basic processes that occur during the turnaround layover period are as follows:

- Passenger alighting and boarding
- Re-stocking of food and beverage service items
- Coach cleaning and re-stocking of bathroom supplies (critical path item)
- Train safety system pre-departure preparation
- In addition, minor equipment repairs that can be accomplished during the layover (parking) period will be addressed.

Facilities would need to be provided at the terminals to support the food service provisioning (commissary), coach cleaning and railroad mechanical department (equipment maintenance and repair). These facilities would need to be located in proximity to the SilverLine platforms, to minimize the time required to access a train when it arrives at the terminal. Dedicated access would be required between these facilities and the SilverLine platforms, separate from the elevators and access points used by passengers.

The SilverLine scheduled terminal station turnaround time is composed of four primary "critical path" factors: Passenger alighting, interior cleaning, passenger boarding, and a "Recovery Time Factor."

Table 13-23 summarizes SilverLine assumptions for the minimum exception and minimum standard scheduled turnaround times.

Table 13-23: Turnaround time

CRITICAL PATH ACTIVITY	MINIMUM EXCEPTION	MINIMUM STANDARD
Passenger Alighting	3 minutes	5 minutes
Cleaning, Restocking, Servicing, Provisioning	10 minutes	15 minutes
Passenger Boarding Window (Includes up to 5 min. 'Recovery Time' Factor	10 minutes	10 minutes
Total Scheduled Turnaround Time Assumption	23 minutes	30 minutes

Note: Train safety system preparations can be accommodated within time windows available for alighting, cleaning and boarding.

Providing a scheduled 10-minute "window" for passenger boarding would permit train cleaning and servicing functions to be concluded prior to the start of the boarding process and minimizes the time spent queuing by departing passengers while also providing for a necessary allowance of up to five minutes of "recovery time" for trains arriving later than scheduled in the timetable.

When there are more trains in operation, the cleaning time during the turn back of trains at terminal stations will become an important factor. Considering the above explained factors, the turn back, including the cleaning time, must be completed within 30 minutes given the current track layout at the Terminal stations. It is necessary to find methods to shorten the cleaning time as much as possible during the turn back operation, such as by increasing the number of cleaning staff and improving the cleaning equipment, and so on.

13.1.13 Timetable Details

Based on the service frequency, the time tabling shall be derived. The time tabling for different horizon varies as the service frequency requirement is varying in the peak hours. The SilverLine operation is planned to conduct in between 05:00 Hrs and 23:00 Hrs. RORO time tabling can be done during non-peak hours and night-time.

It is proposed to start the initial service at 05:00 Hrs from TVM to KGD and KGD to TVM. Similarly, another two services will start from 05:00 Hrs from TSR to TVM and TSR to KGD. The last services will end in TVM and KGD at 22:58 and in TSR at 22:28.

A typical SilverLine train running pattern is provided in the Figure 13-9 considering Loop A, Loop B and Loop C. Detailed time table and operation pattern is attached as Anexure-1 to this report.

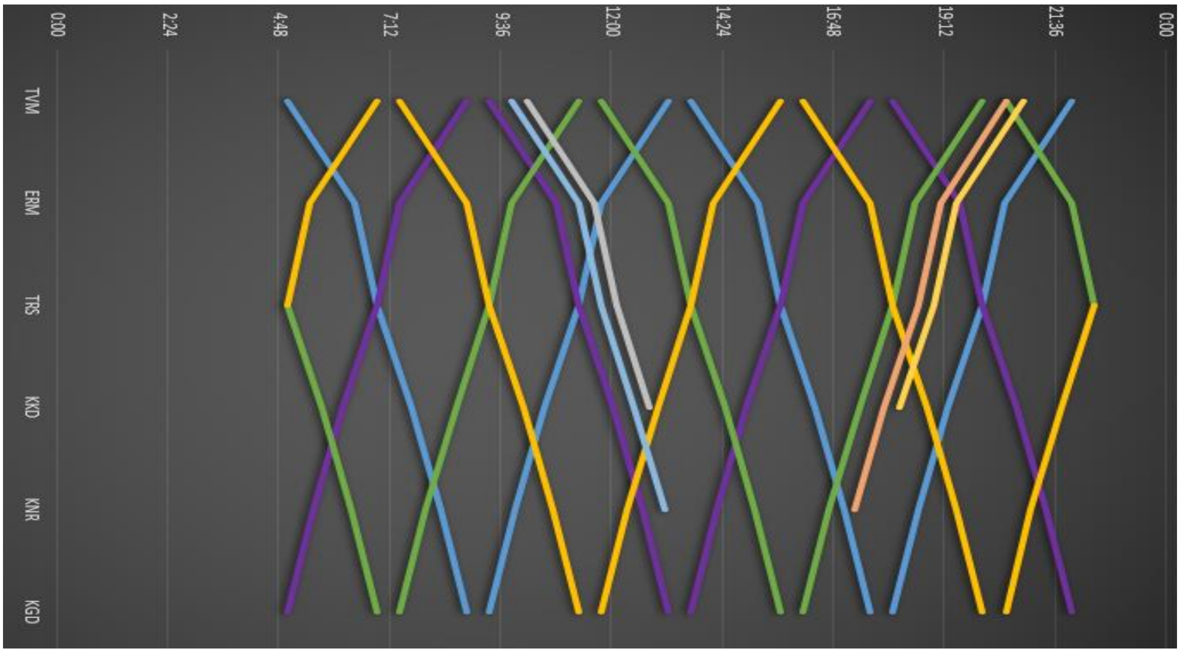


Figure 13-9: Operation Pattern

13.1.14 Station Operation Plan

The service plan encompasses 11 passenger stations. Along with main Terminal stations Thiruvananthapuram and Kasaragod at each end of the SilverLine corridor, Ernakulam, Thrissur, Kozhikode and Kannur are also planned as intermediate Terminal stations. Rest of the stations may be considered as intermediate stations.

Station platforms are assumed to be long enough to accommodate trains with 15 -car length considering the future plans. The terminal stations and the intermediate terminal stations (used for short loop running) are provided with cross overs in both direction for facilitating the reversal operation of the trains. The features of different types of stations, facilities provided for RORO services are detailed below.

13.1.14.1 Intermediate Station Operation

Intermediate stations are normal station with platform length (400 M) enough for 15 Car length train. In this station, the train reversals are not planned during the commercial services. In intermediate stations, SilverLine trains are received in mainline and trains are stopped in the platform. In order to provide precedence to previous trains for any reasons, loop lines are provided on other side of the island platform on both directions traffic.

Facilities such as staircases, escalators and lifts are provided to the passengers for accessing the platform once passengers are entered to the paid area of the stations. The platforms shall be provided with coach numbering so that passengers can identify their pre booked seats within no time. For safety concern, the platform shall be provided with markings to prevent standing of the passengers near to the train while train is approaching the platform. In case of planning run through operation of semi high speed trains in future, barricading shall be provided in platforms to prevent the aerodynamic effect on passengers.

In the case of RORO operation, separate loop lines of approximately 800 m are provided in both direction in all intermediate stations. These loop lines are used for halting the RORO train to give precedence to SilverLine train.

The station operation is managed by the officer in duty at the stations. In addition to the train operation, supporting activities such as cleaning, maintenance of electrical and mechanical facilities etc shall be managed by the officer in duty.

This section covers the specific operation required in Kollam Station. As Kollam Station is located near to the major Depot at Kollam, specific features are provided at Kollam station to facilitate the induction and withdrawal of the trains for commercial operation. As the Depot is located on one side of the mainline, it is difficult to provide interconnection between Depot and main line in both direction because of the geographical constraint. In order to improve process of train induction and withdrawal, a separate platform is provided at the Kollam Station on the Depot side. The platform is used to make the train ready for induction or receive the train for withdrawal. The platform is provided with connection to both direction traffic.

13.1.14.2 Terminal Station Operation

The station operation plan for terminal stations and intermediate terminal stations are listed below. Terminal stations are envisioned to have island platforms serving tracks on both sides and be able to accommodate train cleaning, restocking with on board food service, mandatory train inspection and as-needed maintenance and repair of train set components – along with the alighting and boarding of passengers. These terminal stations shall cater the SilverLine train services. The number of platforms in terminal stations are more compared to intermediate stations in order to manage the reversal activity of both SilverLine trains. Cross over and associated signalling facilities are provided to permit the reversal operation of the trains.

Facilities such as staircases, escalators and lifts are provided to the passengers for accessing the platform once passengers are entered to the paid area of the stations. The platforms shall be provided with coach numbering so that passengers can identify their pre booked seats within no time. Display for showing the coach position and coach numbering are to be provided. For safety concern, the platform shall be provided with markings to prevent standing of the passengers near to the train while train is approaching the platform. In case of planning run through operation of semi high speed trains in future, barricading shall be provided in platforms to prevent the aerodynamic effect on passengers.

In the case of RORO operation, separate loop lines of approximately 800 m are provided in both direction in all intermediate terminal stations. These loop lines are used for halting the RORO train to give precedence to SilverLine train.

The station operation is managed by the officer in duty at the stations. In addition to the train operation, supporting activities such as cleaning, maintenance of electrical and mechanical facilities etc shall be managed by the officer in duty.

Facilities for replenishing the food and beverages shall be provided in the terminal stations. The supply chain activities for the pantry items shall be managed by the respective station officer in duty.

The facilities for crew such as crew rest room, crew signing in room etc shall be provided in the terminal stations.

At terminal stations, train servicing would be done using the passenger platforms or in the loop sidings as per requirement. To maximize passenger safety, servicing operations efficiency, and achieve predictable layover (train parking) times, normal operating procedures would plan for providing temporal separation between the passenger unloading and loading processes and train servicing activities at the terminal platforms.

To attract and keep a dedicated passenger clientele it is important to establish and maintain a cleanliness standard aboard the train consists. This service is accomplished by cleaning techniques implemented at selected times in a service day. Two types of cleaning are envisaged.

- “Normal” (Lay-up) Cleaning – This service is performed at a train storage and maintenance facility and is generally done when a train is parked for a sufficient time to receive a thorough interior cleaning of the passenger areas to include seats and bathrooms. It is usually scheduled daily and is completed prior to a train entering revenue service in the morning. All trash is removed, seats and floors cleaned, and bathrooms sanitized.
- “Light” (Pick-up) Cleaning – When a train turns around (i.e. the rear end of the train arriving at the station becomes the front end of the train departing) in a terminal station or on a storage track with insufficient opportunity for a full normal cleaning, this service is performed to return the interior to an acceptable condition.

Cleaning toilets (and emptying the “holding” tanks) would occur during the overnight layup period at maintenance facilities or sidings and would not be done in the terminals during the turnaround time.

13.1.14.3 RORO Stations

In these stations, the loading and unloading of the trucks to the RORO train is performed. Specific track line for stabling the RORO train for loading/unloading activity is provided in these stations. As per the guidance from K-Rail, five stations are provided with RORO loading and unloading facilities ie. Thiruvananthapuram, Kollam, Ernakulam, Thrissur and Kasaragod.

The RORO Stations shall have platforms and ramps on the RORO loading/unloading track to facilitate the side and end loading of the trucks to the wagons. Similarly, shunting neck also provided on loading track for removing the end locomotive to facilitate the end loading of the trucks to the wagons.

There shall be weighing and gauge checking facilities for checking the weight the dimension of the truck before loading to the wagon. The wagons shall be connected with bridge plate for the inter wagon movement of the trucks.

Staffs shall be deployed to monitor the loading and unloading activities of the trucks. Staffs will ensure the proper locking of the truck with safety measures and ensure the removal of the bridge plate before entering to the commercial service.

Parking shall be provided in RORO stations sufficient for the trucks which are to be loaded on the wagons.

13.1.14.4 Corridor infrastructure

The corridor infrastructure required for operation and maintenance of SilverLine is provided in the diagram Figure 13-10 for reference.

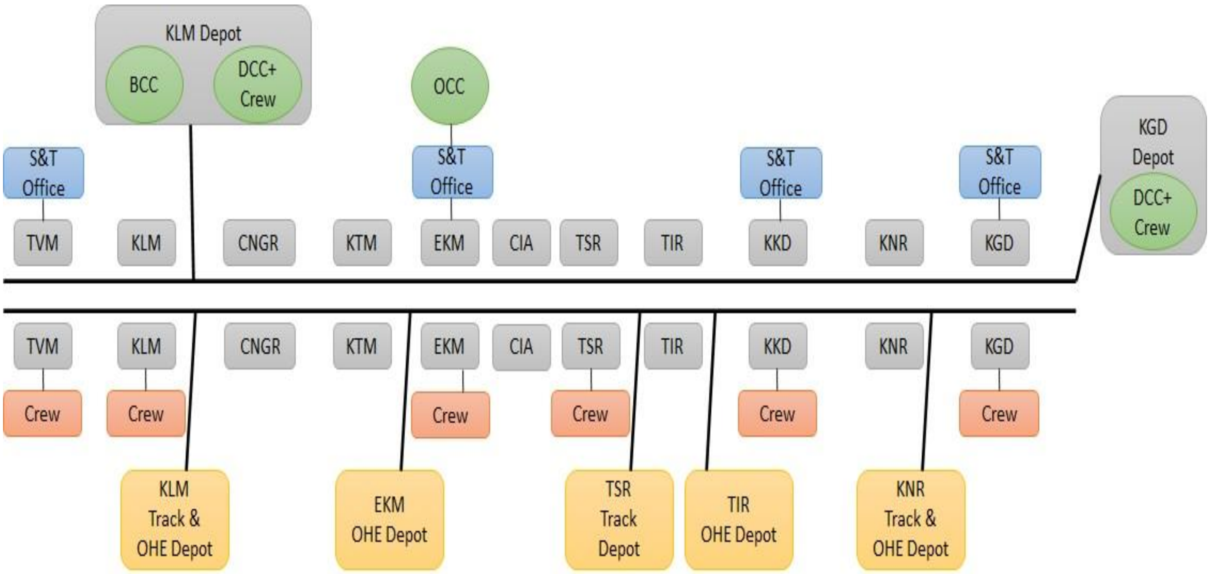


Figure 13-10: Corridor Infrastructure

13.1.15 Depot Operation Plan

For the proposed SilverLine corridor, two Depots are proposed one at the Kollam and second one at the Kasaragod. The operation plan of the two Depots are detailed in the below section.

Kollam Depot is provided with all Depot facilities such as stabling lines, inspection lines and workshop lines and Kasaragod Depot is provided with minimal facilities such as stabling lines and inspection lines.

All types of trains after the commercial operation is stabled either in depot stabling lines or mainline stabling lines. The trains which need inspection as per the schedule is sent to inspection lines in Kollam or Kasaragod as per the convenience. The trains arriving to Depot will undergo toilet waste discharge process, water filling process and automatic washing process. The interior of all the stabled trains in mainline or depot are cleaned during the night-time. All the trains stabled or inspected will undergo a daily inspection after which the trains are ready for commercial operation. Trains ready for revenue operation which are departing from Depots are sent to mainline by Depot Control Centre in coordination with Operation Control Centre.

In Kollam Depot, the trains are sent to specific platform in Kollam Station for induction. The passengers are allowed to board the train from this platform and the train will enter the mainline from this specified platform. In Kasaragod Depot, the trains are directly sent to the mainline platform at Kasaragod station for the revenue service.

The movements of the train inside the Depot is managed by DCC. The Depot lines are designed in such a way that the internal train movements will not interfere the mainline train movements.

13.2 MAINTENANCE PLAN

13.2.1 Introduction

All the assets of SilverLine project shall be maintained properly in order to provide a seamless service to public. To maintain the assets of SilverLine, an Operation & Maintenance organisation need to be set up. The maintenance of major systems may be in-house, and maintenance of minor systems may be outsourced. The strategy will depend to a large extent on the maintenance needs specified by the supplier of the equipment that is purchased and the contractual terms of the purchase – whether maintenance by the supplier will be a part of the contract, what will be the free warranty replacement period etc. it will also depend on the plan for outsourcing some of the maintenance work. Therefore, a detailed maintenance plan cannot be made at this stage. However, the key issues and the broad principles for maintenance can be decided and these are discussed in the following sections.

13.2.2 Maintenance Philosophy

The maintenance practices for the SilverLine must follow the best international practices, suitably modified for Indian local conditions and constraints of the SilverLine. The methodology of maintenance procedures and processes will very much be dependent on the item of equipment. It is envisaged that several differing styles will be employed, such as;

- Time / periodic based or sequenced
- This is where pre-set activities are undertaken at predetermined durations e.g. weekly, monthly, etc. A variation on this theme is that pre-set activities are undertaken when the equipment has been functioning for a predetermined time, such as, hours run, operations complete, etc.
- Condition monitored / appraised / assessed
- The condition of the asset is monitored either, constantly or periodically through telemetry techniques or, periodically through a manual process of inspections,

assessment and appraisal. Once it is determined / predicted that an item is in need of maintenance attention then the relevant works are scoped and initiated.

- Reactive or corrective
- No maintenance is undertaken on an asset until it breaks down. This method is usually employed for components which are referred to as 'maintenance free' e.g. circuit boards, batteries, or where regularly subjecting a component to tests and checks would be more harmful than leaving undisturbed.

13.2.3 Asset Management Plan

An Asset Management Plan for the SilverLine will be prepared. This is a plan to maintain, operate and upgrade if required, the physical assets of the SilverLine cost-effectively. Asset policies form the cornerstone of an effective strategy, providing the pivotal link between strategy for meeting stake holder's or statutory requirements and manage asset base. Assets are designed, constructed, inspected, maintained and replaced in accordance with these policies. Asset management plan is a systematic goal and performance-driven management and decision-making process of operating, maintaining and upgrading transportation assets cost effectively.

13.2.4 Maintenance Plan for SilverLine

Main concepts of maintenance plan proposed for the proposed SilverLine corridor is detailed in this section. It covers the broad activities to be carried out in maintenance and the maintenance time lines without hampering the commercial services.

13.2.4.1 Maintenance Plan for SilverLine

A broad plan for maintenance of the SilverLine assets has been proposed as below:

There will be a maintenance organization set up which will be responsible for the repair and maintenance of all assets of the SilverLine. The organization will consist of engineers, skilled staff and managerial personnel. Some unskilled staff will also be there for manual labour intensive work.

Maintenance of different assets will be done on a preventive and proactive maintenance principle which includes direct maintenance. This means that the condition of assets will be monitored intensively through periodic inspections, onboard computerized monitoring systems and from feedback of operating staff like train operators, station staff etc. This requires a high degree of computerization on the SilverLine where asset condition data will be continuously fed into the computer and reports generated will be available to all maintenance staff. Computerized Maintenance Management Systems (MMS) are now available or can be developed for the SilverLine.

For track maintenance the basic approach for high speed rail system is that track should be built to such standards as to require less frequent maintenance. For example, tamping of track is normally done once in four to six years. Rail fractures are rare. Methodologies for predicting the rate of deterioration have been developed by SHSR systems worldwide. Based on these existing methodologies and computer programs a system shall be developed for this line before start of train operations on the line.

For track maintenance an important part will be removal of long wavelength defects in track once in 3 to 5 years depending on the rate of deterioration of track geometry in a section. Regular measurements of track geometry by Track Recording Cars, and cracks in rail by USFD Rail Testing Cars shall be the main basis for planned track maintenance activities. A comprehensive Track Management System suitable for the needs of SilverLine shall have to be developed before construction of the line is completed.

Minor attention to line side and station equipment will be done at site during night or off-peak service hours. For any major repairs or scheduled maintenance, the item will be brought to the maintenance depot. For attention to fixed assets, this work will be done during non-train operating hours or by taking a block.

A Rolling Stock maintenance depot will be set up at Kollam to undertake maintenance of Rolling Stock as well as S&T. A sub depot at Kasaragod will also be set up, mainly for stabling trains but also for carrying out petty repairs or emergency repairs. Track and Traction Depots are provided on the mainline for better access and maintenance. Currently four track and traction depots are proposed along the corridor.

All departments must coordinate their working during traffic block hours so that the possession is effectively utilized.

All crucial safety related maintenance work must be done in house with trained staff of the SilverLine. Some non-core activities like building maintenance, road transport, housekeeping work etc. can be outsourced to private parties.

Maintenance of certain assets like the signalling system, rolling stock etc can be given to the supplier of the system, but this must be covered by strict contractual obligations and responsibilities in case of accidents.

Annual maintenance contract must be given for sophisticated sub systems like computer network, S&T equipment modules, POH of track machines and locomotives etc. The work done by the private parties must be strictly monitored by the SilverLine staff. Renewal of assets must be done after their economic life is over. The time of renewal will depend on the condition, the stated life of the asset as per the manufacturer, intensity of use etc.

13.2.4.2 Timelines for Maintenance

The time slot for the maintenance of mainline track, OHE, S&T equipment and other equipment in mainline is allocated during the night-time. In addition to the SilverLine passenger services, RORO services are also planned to run on the same corridor. The operation time for the passenger trains are from 05:00 Hrs to 23:00 Hrs. During this period, a portion of the RORO trips also managed in the non-peak hours. The balance trips of RORO are conducted during the night- time from 23:00 Hrs to 05:00 Hrs. Hence the time for maintenance period is very limited when the RORO services are conducted during night-time.

The maintenance time is allocated when there is no service in both tracks of the corridor. As safety is important in semi high speed operation, the segregation between operation time and maintenance time is up most important. Hence it is recommended to issue section for maintenance when there is no train operation in both lines.

In order to find a schedule to maintain the mainline assets with RORO services and no traffic in both tracks, two approaches are adopted.

- When RORO services are conducted, the time slot after RORO passing and before next passenger services or other track RORO service is allocated for maintenance. Sections having no trains in the section for more than two hours are allowed to conduct maintenance considering the safety aspect. It shall be noted that last RORO service will start before 00:00 Hrs.
- To maintain the sections which are not covered in the first point, RORO services may suspend on two days per week. Hence the night-time between last passenger service and first passenger service next day is used for maintenance of mainline assets.

A pictorial representation of the maintenance time allocated for two scenarios as detailed above is shown in Figure 13-11 and Figure 13-12.

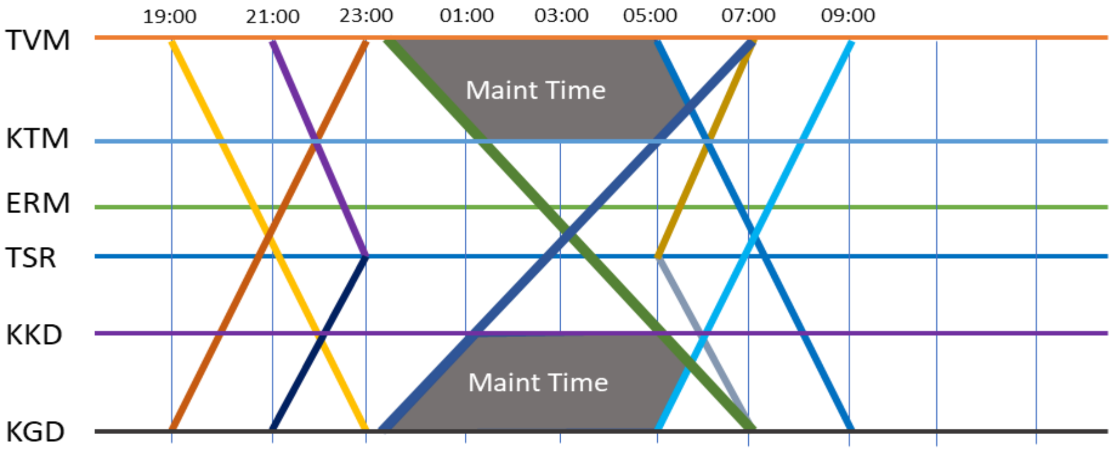


Figure 13-11: Maintenance time period with RORO services

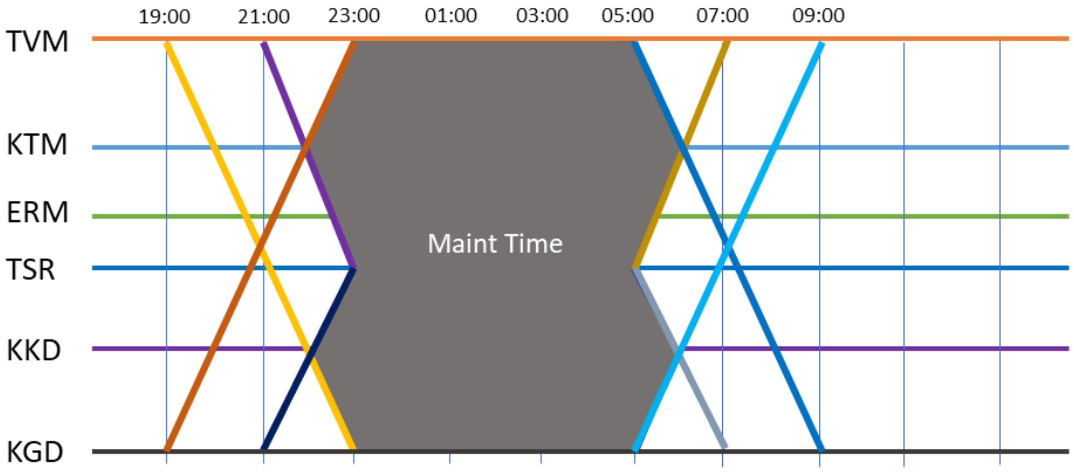


Figure 13-12: Maintenance time period without RORO services

It may be noted that the above time period for maintenance is the end to end maintenance period. Within this period all safety process of maintenance block issue, carrying maintenance activity of the asset and restoration of asset for operation are to be conducted.

13.2.5 Rolling Stock Maintenance Plan

13.2.5.1 Introduction

The Rolling Stock shall be maintained with the aim to achieve and to guarantee a defined performance and a correct degree of vehicle availability/reliability for scheduled operation. Appropriate maintenance of rolling stock, which consists of preventive and breakdown maintenance, is a key to guarantee safe and reliable operation of railways and an inevitable/essential basis for safe and highly reliable operation of rolling stock.

Despite that the equipment/facilities at depots and workshops are an important infrastructure to be used for 50 to 100 years, they shall be able to flexibly cope with changes and developments of rolling stock.

The maintenance shall ensure:

- maximum train availability and reliability,
- maximum safety conditions,
- best quality of service for passengers,
- low cost of maintenance activities.

Maintenance covers all functions of maintaining or restoring the rolling stock to normal operating condition.

The operations study has determined the number of trains and the train composition that will be required for the SilverLine Corridor. By the year 2052, there will be a total number of 46 rakes which will be needed to carry the estimated passengers. In addition to SilverLine trains, 6 RORO trains with 2 locos and 40 wagons are to be maintained in the Depots.

13.2.5.2 Types of Maintenance Operations

13.2.5.2.1 Daily Maintenance

Daily inspections are performed on a complete vehicle in order to check the safety components and wearing parts exchange.

The daily maintenance activities shall include:

- visual safety checking,
- Subsystems checking through user interface
- automated exterior cleaning,
- interior light cleaning,
- tanks refilling and wastage cleaning
- small repairs.

These activities are generally performed in inspection bay line, automatic washing machine or stabling line area.

13.2.5.2.2 Preventive Maintenance

This is the set of actions to be performed according to pre-established criteria to reduce train failure probability.

These actions are carried out according to a programme based on elapsed time, train mileage or condition of the equipment.

These operations consist of:

- routine operations, such as filling, topping up, change oil, greasing, etc.;
- scheduled replacement operations;
- checks, at specified time intervals, whose outcome determines whether or not replacements will be performed;
- general overhauls of systems and subsystems of the train set.

These activities are normally performed in Inspection Bay Lines (IBL) and in some cases in the Workshop Bay Lines (WBL).

13.2.5.2.3 Corrective Maintenance

Corrective maintenance is defined as any operation which is not scheduled or anticipated. The corrective maintenance is defined by all troubleshooting and repair actions taken to get the equipment back into operating condition after a failure has altered or removed its aptitude to ensure the required function. To minimize the train down time, the corrective maintenance can be performed by replacing some subsystems or component which can be subsequently repaired off train.

Corrective maintenance covers:

- Incidents and failures observed during operation and which need to be repaired;
- Incidents and failures observed during checking carried out during preventive maintenance operations.
- Wheel reprofiling in case of wheel uneven wearing.

These activities are normally performed in Workshop Bay Lines (IBL).

13.2.5.2.4 Exceptional Maintenance Activities

Exceptional maintenance includes all the activities with very rare occurrence as for example:

- Interventions in track operation after derailment for example,
- Half-life overhaul (about 15 years),
- Heavy repairs after a crash.

13.2.5.3 Maintenance Means

To perform maintenance activities the following means are necessary:

- Labour (manpower),
- maintenance documentation,

- tools and test equipment,
- spare parts (main and consumables),
- workshop or infrastructure equipment,

13.2.5.3.1 Labour

Trained staff shall be provided for doing the maintenance appropriately and safely. Training shall be comprehensive and will allow the trained staff to perform all maintenance activities.

13.2.5.3.2 Operation & Maintenance Documentation

The maintenance shall be carried out as per the specified maintenance documentation. The preparation of the operation & maintenance manual and catalogues is the most important activity in the whole maintenance planning.

The operating manual normally covers the details as below:

- the preparation instructions,
- the driving instructions,
- the cab change instructions,
- parking instructions,
- safety instructions,
- operating instructions,
- degraded mode instructions,
- rescue mode instructions etc.

13.2.5.3.3 Maintenance Manual

The maintenance manual is normally provided by the Rolling Stock manufacturer based on the design, RAMS requirement and manufacturer experiences and client expectations. The maintenance manuals normally cover the following details:

- preventive maintenance manuals or instructions,
    - detailed tasks with operative procedures and tools,
    - test points and measurements with limit values and actions to perform.
    - the consistency of the maintenance operations, the procedures with the localization of the test points, the limit values and the actions to be undertaken according to the results,
    - a detailed description of the on board maintenance assistance tools,
    - description of the tools and/or test equipment and utilization manuals,
    - a list of consumable parts necessary to the operations of maintenance,
    - the specific safety rules.
- corrective maintenance manuals or instructions,
    - technical descriptions of the sub-systems, equipment and components,
    - electrical parameters, test points,
    - diagnostic procedures, failure arborescence,
    - disassembling and assembling procedures,
    - description of repair and test tools,
    - test procedures after repairing, etc.

- catalogue of spare parts,
    - Classification of the parts,
    - Name of the parts,
    - Reference number of the parts,
    - Reference as well as sub-supplier's reference number,
    - Reference drawing number of the parts,
    - Specification of the parts.

13.2.5.3.4 Tools and Test Equipment

Special tools are considered the tools which are specific for the supplied rolling stock and needed to perform the maintenance activities. The operating procedures, instructions to use and maintain these special tools and equipment shall be described in the maintenance documentation

13.2.5.3.5 Spare Parts

The spare parts shall be classified in three principal categories:

- Main spare parts- The main spare parts are expensive parts as bogies, converters, current collectors, main circuit breakers, traction motors, air compressors, complete doors, HVAC units etc. precisely identified.
- Wearing parts for general use- The wearing parts are usual parts as wheels, brake shoes, pantograph carbon strips etc. replaced when they are worn after normal service.
- Consumables-The consumables are the elementary parts (no specific railway components) or fixing components such as locks, screws, nuts, oil, grease, filters, detergents, cleaning fluids etc. needed for proper functioning of the rolling stock or its maintenance.

13.2.5.4 Maintenance Levels

In order to optimize the manpower available and to reach the objective of an efficient maintenance, analysis of maintenance process was done, which resulted in a classification into levels according to the complexity of maintenance operations. The maintenance requirement for the rolling stock will depend on the manufacturer. Each manufacturer of rolling stock will have his own recommended maintenance schedules and therefore the design of the facilities in the depot will depend on the rolling stock finally chosen. However, we referred main high-speed rolling stock maintenance schedule in Japan, China, Europe and Australia (DPR). Accordingly going by general international standards, we can assume that the following maintenance will be needed which can be optimised during the detailed design.

Table 13-24: Maintenance Levels SH RS

Level	Frequency
Level 0	Daily
Level 1	4000 KM or 48 Hours

Level	Frequency
Level 2	20,000 KM or 15 Days
Level 3	80,000 KM or 45 Days
Level 4	240,000 KM or 180 Days
Level 5	480,000 KM or 1 Year
Level 6	1,200,000 KM or 3 Years
Level 7	2,400,000 KM or 6 Years

13.2.5.4.1 Level 0

Level 0 maintenance is carried out daily on every operating trains. The basic characteristics of the first level of maintenance are:

- Only simple actions necessary for train operation,
- General Visual Inspection.
- No specific tools required.

It is carried out in Mainline or Stabling Line in Depot. It requires approximately 30 minutes to perform.

13.2.5.4.2 Level 1

Level 1 maintenance is carried out on 4000 KM mileage or 48 Hours. Trains to be brought to conduct this maintenance. Two characteristics for the level 1 of maintenance are:

- actions that require simple procedures and/or simple to use support equipment,
- actions limited to less than 3 hours.

It mainly includes the following activities:

- Daily inspection, consumables replacement, and cleaning operation.
- The waste collection tanks of WC closed toilets are emptied, and freshwater tanks are refilled.
- Visual inspection of wheel sets and bogies.
- Check status of bogie, wheels, pantograph, doors and other items while cars are connected.
- Check train functions inspect pantograph contact strips and brake linings.
- Replace consumable for brakes, pantographs and other items.

It is carried out in Inspection Bay Line in Depot. It requires approximately 2 Hours to perform.

13.2.5.4.3 Level 2

Level 2 maintenance is carried out on 20,000 KM mileage or 15 Days. Maintenance of level two is characterized by one main line: operations that require complex procedures and/or complex activities requiring to use support equipment.

It mainly includes the following activities:

- The brakes, the on-board signalling systems and the anti-skid equipment are checked.
- Train function test through the driving-cab monitoring system.
- Inspects/checks the mechanical functions of controllers and the brake riggings.
- Inspection of controllers for VVVF inverters and thyristor phase control systems.
- Inspectors check the wheel treads, wheel systems and axles for flaws, check the driving gears and check the brake lining for wear and replace.
- Gearbox change oil and wheel tread repair. (if required)

It is carried out in Inspection Bay Line in Depot. It requires approximately 4 Hours to perform.

13.2.5.4.4 Level 3

Level 3 maintenance is carried out on 80,000 KM mileage or 45 Days. This includes additional maintenance checks in comparison to Level 2.

It mainly includes the following activities:

- Brakes thorough check
- air conditioning check
- Pantry equipment check
- The batteries check
- The seats and the passenger information system check
- Ultrasonic flaw detection

It is carried out in Inspection Bay Line in Depot. It requires approximately 8 Hours to perform.

13.2.5.4.5 Level 4

Level 4 maintenance is carried out on 240,000 KM mileage or 180 Days. This includes additional maintenance checks in comparison to Level 3.

It mainly includes the following activities:

- Check of the electric traction motors,
- Check of the axle boxes, the wheel sets
- Check of the couplers

It is carried out in Inspection Bay Line in Depot. It requires approximately 12 Hours to perform.

13.2.5.4.6 Level 5

Level 5 maintenance is carried out on 480,000 KM mileage or One-year. Maintenance of level five is defined by operations that require the use of a specific technique or technology and/or specific support equipment. It mainly focuses on the Bogie maintenance.

It mainly covers the following activities:

- Bogie inspection and maintenance
- Inspect the wheel sets, wheels, axles, driving gears, traction motors and riggings
- All the bogies are exchanged wit spare bogies that have already been inspected
- After completion of the bogie inspection, each bogie is subjected is to a car running test as a final check under the same conditions as those of actual train operation.
- Pneumatic systems, the transformer cooling

It is carried out in Workshop Bay Line in Depot. It requires approximately 28 Hours to perform.

13.2.5.4.7 Level 6

Level 6 maintenance is carried out on 1,200,000 KM mileage or Three years. It includes the activities to perform the intermediate overhaul required for the Rolling Stock. Level six is independent and includes operations that require know-how, based on techniques or technologies, process and/or support equipment.

It mainly covers the following activities:

- To disassemble each subsystem of the Rolling Stock for inspection and maintenance and the Rolling Stock is painted again (if required).
- Bogies and all major components are disassembled from the carboy Cars, air-conditioners, pantographs and some other components are exchanged with spares that have already been inspected and maintained under a spare component circulating system
- The thorough inspections conducted on every part of cars.

It is carried out in Workshop Bay Line in Depot. It requires approximately 10 Days to perform.

13.2.5.4.8 Level 7

Level 7 maintenance is carried out on 2,400,000 KM mileage or Six years. It includes the activities to perform the periodic overhaul required for the Rolling Stock.

It mainly covers the following activities:

- Train bogies are exchanged for new ones completely overhauled
- All major train components are disassembled and checked
- The Rolling Stock needs overhauling and most of Rolling Stock parts are replaced

It is carried out in Workshop Bay Line in Depot. It requires approximately 20 Days to perform.

After completing the above levels of preventive maintenance activities, a mid life refurbishment is to be carried out at approximately 15 years. After mid-life refurbishment, the car will be returned to a condition that will enable them to run until the expiry of their design lives without major attention.

13.2.5.4.9 Cleaning of Rolling Stock

The following frequency and cleaning activities are proposed for the Rolling Stock maintenance.

Table 13-25: Cleaning Frequency

Cleaning Type	Frequency	Line Required
Daily Cleaning Exterior	Daily	Automatic Washing Plant
Daily Interior Cleaning	Daily	Stabling Bay Line (In Depot & Main Line)
Interior Light Cleaning	One Week	Stabling Bay Line
Heavy Interior and Exterior Cleaning	One Month	Heavy Cleaning Bay

In addition to this it is proposed to clean the Rolling Stock in each turn back at the terminal stations during the operation.

13.2.5.5 RORO Locomotive & Wagon Maintenance

The RORO train consists of two locomotives and 40 wagons. The maintenance schedule followed by Indian Railway is taken as a reference for determining the maintenance plan of Locomotives and Wagons. There will be 6 RORO train servicing in the corridor.

The maintenance plan of RORO locomotive is provided in Table 13-26.

Table 13-26: Maintenance Plan RORO Locomotive

Level	Frequency
Trip Inspection	45 Days
Service Inspection- IA	90 Days
Service Inspection- IB	180 Days
Service Inspection- IC	270 Days

Level	Frequency
Major Overhaul- MOH	18 Months
Intermediate Overhaul- IOH	6 Years
Periodic Overhaul- POH	12 Years

The maintenance plan of RORO wagon is provided in Table 13-27.

Table 13-27: Maintenance Plan RORO Wagon

Level	Frequency
Major Overhaul- MOH	18 Months
Periodic Overhaul- POH	12 Years

The maintenance of the RORO Locomotives and the Wagons will be carried out in same facilities provided in Kollam and Kasaragod Depot. The Depot buildings and Machinery & plants are designed to cater the maintenance of two types of train viz. SilverLine trains and RORO trains.

13.2.5.6 Asset Management

An Asset Management Plan is used to maintain, operate and upgrade if required, the physical assets of the SilverLine cost-effectively. Asset policies form the cornerstone of an effective strategy, providing the pivotal link between strategy for meeting stake holder’s or statutory requirements and manage asset base. Assets are designed, constructed, inspected, maintained and replaced in accordance with these policies. Asset management plan is a systematic goal and performance-driven management and decision-making process of operating, maintaining and upgrading transportation assets cost effectively.

Asset management policy, along with the asset policies for sub systems, should be framed by the SilverLine to cover the full life cycle management of physical assets from design, construction, operation, inspection and maintenance to take decision for renewal, alteration or replacement.

Asset management policies shall be centred on a risk-based methodology. This methodology shall be used to identify the risks to the delivery of objectives, and to manage these risks by:

- An initial fit-for-purpose asset or system design;
- An inspection regime to monitor asset condition and identify actual or potential defects that could compromise the performance of the asset;
- Maintenance activities to address degradation identified at the time of inspection or to address predictable asset degradation; and

- Renewal criteria that identify when the current asset or system should be replaced as ongoing maintenance is considered to be uneconomic.

The following asset management principles shall be adopted:

- Asset management regime shall adopt following principles that reflect objectives and values of asset management:
- Asset investment plans shall balance maintenance and renewal work with the aim of minimizing whole life costs for the whole network;
- Prevent increase in the risk to passengers and workers by degradation or failure of infrastructure and reduce it where reasonably practicable;
- Develop technology and methods to support fact based decisions on maintaining and renewing the infrastructure improving capability for predicting and preventing failures;
- Use a risk management process to identify and reduce threats to meet objectives
- Develop asset policies, standards and plans through consensus, to improve their practicality, to encourage consistency and to help long-term maintainability.
- Asset Management System

Efficient Asset management system shall be established using suitable modern computer based solutions to maintain huge database and modern tools for asset management. AMS should also incorporate environmental and hazard management and emergency response systems. Once integrated, an AMS should serve the needs of all the parties that are in any-way connected to the railway system, such as the infrastructure owners, outsourced maintenance or operating agencies etc. They all should make use of the AMS, extract the data needed for their everyday or long-term strategic purposes, and also feed the appropriate data back to the system. AMS shall be able to handle following activities:

- Keeping record of information & location of all assets constituting Railway infrastructure i.e. keeping record of what the assets are and where they are located
- Monitoring and storing information about condition of all assets
- Infrastructure life cycle management
- List other assets and their condition, including, but not limited to, construction and maintenance equipment, vehicles, real estate, materials, corporate data and information
- Include deterioration rates for infrastructure assets; and
- Determine funds (short-term as well as long-term) necessary to fund infrastructure maintenance at the recommended performance level.

13.2.5.7 Condition Monitoring

Condition monitoring shall be deployed for the Rolling Stock maintenance. Condition monitoring will reduce the maintenance cost considerably. Condition monitoring is measurement of parameter(s) of condition of any equipment at pre-decided interval of time/space by suitable measuring device. For condition monitoring, there must be a measurable deviation of the parameter from normal/expected/reference value.

The onboard control electronics play vital role in the condition monitoring. The on board electronics and Train control software can monitor individual subsystems and can give indication on abnormal activity. This will in turn lead to appropriate maintenance of the subsystem before failure of the subsystem or component.

Way side measuring system is also proposed along the corridor for detecting the failures in the Rolling Stock. This will relay the abnormal activity to maintenance centre and attention can be given to the Rolling Stock before the failure of the Rolling Stock.

Condition monitoring will improve the reliability and availability of the Rolling Stock by doing proactive maintenance instead of preventive and corrective maintenance.

13.2.6 Traction System Maintenance Plan

To achieve high reliability and zero defects on Overhead Contact System (OCS), it is necessary to maintain the OCS in perfect condition through proper schedule maintenance/checks on its geometry and all parameters adopted in the design without compromising on safety of the equipment as well as personnel. The OCS is subjected to dynamic oscillations due to the movement of the fast-moving pantograph and wind pressure. It comprises huge number of insulators, fittings and accessories. The failure of any one may result in interruption of train services for substantial period until the defect/ breakdown is rectified.

13.2.6.1 Maintenance Depot

Four electrical maintenance depots shall be planned for this project (Approximately 130km intervals).

13.2.6.2 Manpower requirement

Mainline and depot power supply and traction staffs do the regular inspection of overhead contact system, Traction substation, SCADA system and other electrical equipment, make the plan for repairing work and do the inspection completion. It is also proposed to hire an outsourced agency for doing the repairing works.

13.2.6.3 Tower cars for maintenance of overhead contact system

Six numbers of OCS tower cars are proposed. 2 near to the end of the corridor section and 2 at midsection of corridor and 1 at each depot.

Table 13-28: Tower Car Requirement

	Electric maintenance depot – 1 (End)	Electric maintenance depot – 2	Electric maintenance depot – 3	Electric maintenance depot – 4 (End)
Tower car	1	2	2	1

Though the detailed maintenance schedule and the periodicity are given by the equipment suppliers, which are normally adopted. The broad maintenance requirement is given below.

13.2.6.4 Traction substations

Since reliability of electric traction depends upon continues availability of power supply. Substations and switching stations shall be kept in proper working at all the time. Transformers, Control and Relay panel and associated switch gears are to be duplicated so that if one unit fails, the stand by unit can be brought into service to continue power supply

All switching operations are centralized and controlled through SCADA by Traction Power Controller.

Following equipment shall be maintained properly to have the reliable supply from substations;

- Outdoor Substations – Air insulated substation

The Table 13-29 shows the maintenance schedule of Air insulated substation

Table 13-29: Maintenance Plan Air Insulated Substation

Sr No	Equipment	Yearly	Half yearly	Quarterly	Monthly
1	Lightning arrester	✓	✓		
2	Current Transformer	✓	✓		
3	Potential Transformer	✓	✓	✓	
4	Isolator	✓	✓	✓	
5	SF- 6 Circuit breaker	✓	✓	✓	
6	Power Transformer	✓	✓		✓
7	Neutral Grounding Resistor	✓	✓	✓	
8	Earth pit	✓	✓		
9	Control and Relay panel	✓		✓	
10	25kV switch gear	✓	✓		
11	Battery bank	✓	✓		✓
12	Battery charger	✓		✓	✓

Sr No	Equipment	Yearly	Half yearly	Quarterly	Monthly
13	Auxiliary Transformer - Dry type	✓	✓	✓	
14	AC DB	✓	✓	✓	

13.2.6.5 Overhead Contact System

The following schedules of maintenance for OCS are to be carried out;

1. Foot Patrolling
2. Current collection Test
3. Special Checks
4. Annual maintenance checks
5. Checks by OCS inspection car
6. Periodical Checks
7. Re-tensioning of unregulated OCS
8. Condition based maintenance through thermo vision camera

13.2.6.5.1 Foot Patrolling

An authorized OCS linesman is deputed to inspect the OCS, masts and feeder line, SP ,SSP by walking along the track .Any defects , abnormalities noticed by the foot patrolling linesman are recorded and given to the OCS supervisor for further needful action . The linesman must observe the pantograph of moving trains and any abnormal oscillation of the OSC shall be immediately reported.

13.2.6.5.2 Current collection Test

Current collection tests are carried out at nights to observe the sparking in the contact wire while the panto passes at high speeds of fast-moving trains. A bad contact wire with kinky and loose dropper clips, jumper connections and steady arm swivel clips will hamper the smooth movement of pantos contributing to sparks and flash. Any defect in the pantograph articulated fixing springs and jerks in locos can be other reason for bad current collection.

13.2.6.5.3 Special Checks

a. Insulators
b. Section Insulators
c. Isolating switches
d. Bi- metallic clamps
e. Earth connections
f. OCS support on steel girder
g. Bird nests
h. Pre - summer checks
i. Pre - monsoon checks

a. Insulators

- Normally insulator needs cleaning once a year along with the annual maintenance schedule, where there is no pollution.
- Where pollution is not high, the interval may be three months or longer depending upon the degree of pollution in the area.
- Where pollution is heavy, more frequent cleaning of insulators are required.
- The affected section should be divided into various zones based on the degree and nature of pollution and periodicity of insulator cleaning may be fixed suitably.

b. Section Insulators

Section insulators on the main lines' neutral sections, passenger yards and sidings should be attended to once in three months as follows:

- Clean insulators and replace badly chipped or even slightly cracked insulator.
- Check runners for flash mark.
- Check level of the assembly and adjust as required.
- Check for excessive contact wire wear near anchor clamp.
- Tighten the PG clamps of droppers and stiffener properly.
- Check that pantograph passes underneath the section insulator smoothly.

c. Isolating switches

The continuity and soundness of earth connections should be checked once a month.

d. Bi- metallic clamps

Tightness and overheating shall be checked once in three months.

e. Earth connections

Apart from general inspection of bond and earthing connections during foot patrolling, all such connections should be specially checked for continuity and soundness of connections once in six months.

f. OCS support on steel girder

OCS support on steel girder bridge should be examined as possible depending upon traffic movement.

g. Bird nests

Precaution should be taken care during the nesting season and the nests removed as soon as possible.

h. Pre - summer checks

Table 13-30: Pre-Summer Checks

1	Overhead crossing	Check all power line crossing for broken and loose guard wire
2	Bird nest	Remove all bird nest from OCS, transmission line and other nearby structure as FOB/ROB/platform sheds etc.
3	ATD	Remove all kite threads and polythene from OCS, transmission line and other nearby structure as FOB/ROB/platform sheds etc.
4	Jumper	Loose jumpers shall be tightened
5	Anti- creep	Anti- creep having excessive sag should be tightened
6	FOB/ROB	Clearance of OCS under FOB/ROB should be checked

i. Pre – monsoon checks

- Check the condition of insulators specially that of section insulator at major yards having mixed type of traction.
- Check the over line structure for any water leakage on the OHE.
- Trimming of trees branches near to OHE.
- Check the condition of embankments with respect to stability of mast.
- Ensure that proper drainage of rain water surrounding the OHE foundation/ OHE mast.

13.2.6.5.4 Annual maintenance test

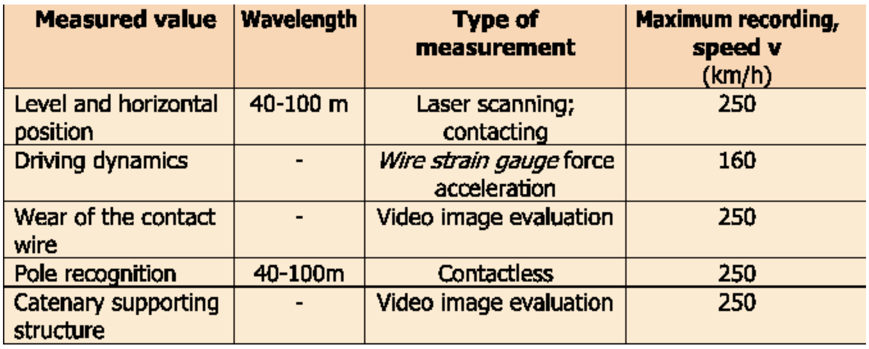
Annual maintenance of the following equipment shall be performed

1. Masts, Portals and cantilever supports
2. Contact, catenary and feeder wire
3. Droppers
4. Turnouts
    a. With OCS inspection car running on main line check-up if pantograph glides smoothly under the loop line OCS
    b. With OCS inspection car running on loop line check-up if pantograph glides smoothly under the main line OCS
    c. Check the stagger of both the OCS at turn outs
5. Section insulator assemblies
6. Isolators
7. Overlap
8. Neutral section

9. Overline structure/Tunnels /Cut and cover
    a. Check and record horizontal clearances and adjust OCS as required
    b. Check for the flash mark on the underside of the bridge structure
    c. Check the height of the contact wire
    d. Check the gradient of the contact wire on either side
10. Level crossing
    a. Check height and gradient of contact wire
11. Regulating equipment
12. Bonds and Earthing connection
13. PG clamps

Table 13-31 gives a list of parameters which can be recorded for the overhead line, as well as their marginal conditions according to the state of the art.

Table 13-31: Maximum Recording Speed



Measured value	**Wavelength**	**Type of measurement**	**Maximum recording, speed v** (km/h)
Level and horizontal position	40-100 m	Laser scanning; contacting	250
Driving dynamics	-	*Wire strain gauge* force acceleration	160
Wear of the contact wire	-	Video image evaluation	250
Pole recognition	40-100m	Contactless	250
Catenary supporting structure	-	Video image evaluation	250

Non-contact optical laser scanners are used to determine the horizontal position (zigzag) and the level of the overhead line. The measure and record in real time up to 4 contact wires. Sinusoidally modulated laser beams are used for this purpose. The light reflected by the overhead line is collected by a detector. The distance can be determined from the phase displacement between the emitted and the received light. The horizontal position and the level of the contact wires can be calculated by using the scan angle and the distance measured. Figure 13-13 shows the laser scanner for the determination of the contact wire position in the centre and on the left and right-hand sides the measuring equipment for the determination of the position of the masts.

Due to the use of laser radar technique for mast recognition (and the position of the contact wire bracket) the system becomes insensitive to external light (such as daylight or darkness). Therefore, measurement can be performed also in tunnels and on bridges. If two mat recognition unit are used, the position of the masts can be determined exactly even if there are interfering objects. Digital cameras are used to measure the wear of the contact wire. The resolution of the measurement is 0.1mm.

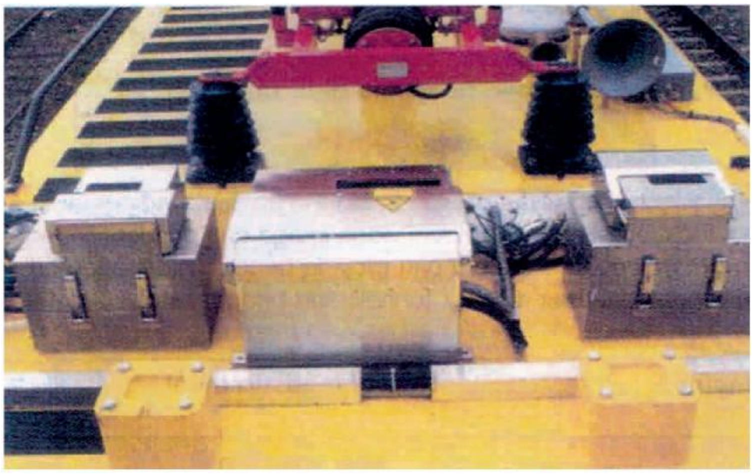


Figure 13-13: Determination of the position of the overhead line and mast recognition

The horizontal and vertical contact forces, the position of the contact wire on the slippers, the acceleration at the current collector and the position of entering and exiting contact wires of intersection catenary suspension on the current collector can be measured with contact load sensing devices. Force sensors are fitted at the ends of pantograph slippers (wire strain gauge technique) and the total of both measured signals of a slipper equals the acting contact forces. The position of the entering and exiting contact wires of intersecting catenary suspensions is measured with the help of inductive proximity sensors in the horn of the pantograph.

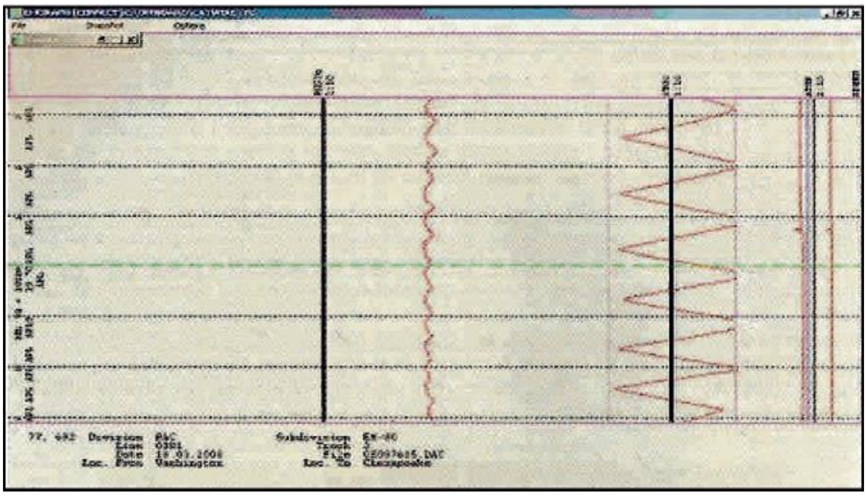


Figure 13-14: Monitor image of an overhead line determination

13.2.6.5.5 Periodical overhaul

The object of POH is to recondition and restore the installation in the condition it was when it was first commissioned, whereas preventive maintenance has for its objective to take care of the wear and tear during normal service and forestalling possible failures by regular inspection and quick attention. The POH should be thorough and cover every part of the installation.

13.2.6.5.6 Re - tensioning of unregulated OCS

The re - tensioning of unregulated OCS in accordance with the tension temperature chart should be done normally at the end of 6 months from the date of erection and again at the end of 12 months. There after the tension should be checked up once in 2 years and re tensioning done as required

13.2.6.5.7 Condition based inspection through Thermal image camera

Thermal imaging infrared camera identifies electrical and mechanical problems like hot spots, heat development on loose connections etc. before they result in failures. It is a non-contact device which detects infrared radiations and converts it into electronic signals. These signals are then processed to produce thermal image of the object.

13.2.6.6 Maintenance check list for RTU, OCC, BCC and SAS equipment

The Table 13-32 shows the maintenance schedule of RTU, Servers and SAS system

Table 13-32: SCADA Maintenance Plan

Sr No	Equipment	Half yearly	Quarterly
1	Remote Terminal Unit (RTU)	✓	✓
2	OCC workstation		✓
3	BCC workstation		✓
4	SAS workstation		✓
5	OCC server	✓	
6	BCC server	✓	
7	SAS server	✓	

13.2.7 Track Maintenance Plan

13.2.7.1 Life Cycle of the Track Components

Table 13-33: Life Cycle of Track components

Tamping	40-70 mio. t	4-5 years
Grinding	20-30 mio. t	1-3 years
Cleaning	150-300 mio. t	12-15 years
Rail replacement	300-1000 mio. t	10-15 years

Replacement of concrete sleepers	300-700 mio. t	30-40 years
Rail fastenings	100-500 mio. t	10-30 years
Replacement of ballast	250-500 mio. t	20-30 years
Rehabilitated subsoil	> 500 mio. t	> 40 years

Nowadays, the DB AG expects maintenance cycles of 8 years of primary track. Cleaning is performed only during renewal (about every 30 years for tracks on concrete sleepers). The lifetime of the rails is about half the lifetime of the track (approx. 15 years) and this limit is usually not caused by rail wear, but by defects on the rail surface. The ballast is usually replaced during track renewal (i.e., after 30 years).

13.2.7.2 Theoretical wavelength criteria

Track geometry is described by track profile, cross level, alignment and gauge. As a vehicle travels, it responds to track geometry variations and irregularity. The chord length of 9.6 m and 7.2 m for measurement of top and alignment respectively are grossly inadequate in correctly assessing the track irregularity for high-speed operation.
The wavelength of track irregularities, which leads to sway the coach, depends on the natural frequency of the vehicle and speed. The relation among these three parameters can be expressed mathematically in the following form:

$V = f\lambda$, Where

V = Speed of vehicle in meter/second

f = Natural frequency of the vehicle in hz

λ= wavelength of the track irregularity causing sway/resonance in the vehicle in meters.

For natural frequency value of one, the vehicle proposed to run on the particular line, the wavelength for different speeds are as follows:

(a) For high speed v=200 kmph & f=1Hz
λ = **55.55m**
(b) For high speed v=250 kmph & f=1Hz λ= **69.45m**
(c) For high speed v=300 kmph & f=1Hz λ =**83.33m**
(d) For high speed v=350 kmph & f = 1Hz λ =**97m**

Hence, track defects of wavelength 80-100 m are prone to create resonance for very high speed.

All the vehicles plying on any line will not have a uniform natural frequency and speed on whole route cannot be uniform due to various reasons the wavelengths to be controlled remain in a band width. On IR, the frequency of ICF coaches is 1 Hz approximately. On Japanese Railway passenger rail vehicles tend to sway at natural frequencies between 1.0 to 1.5 hzs.

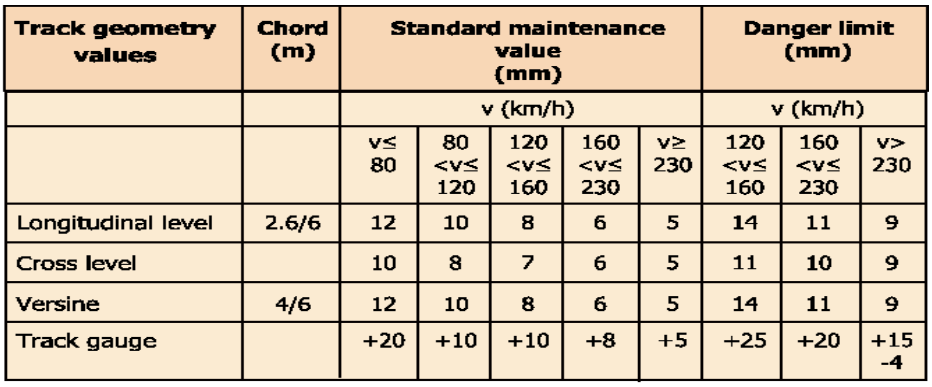
Since the natural frequency of carriages designed for high-speed is low, generally less than 1 Hz long wavelength anomalies provide dynamic input to the high-speed passenger vehicles and can excite car body modes at high speeds. At speeds of 350 km/h track irregularity up to 100 m wavelength would be important.

13.2.7.3 Standard values of track tolerance for High speed on standard gauge

For high speed routes it is very necessary to know the limit of track parameters in the form of tolerances, so that track can be maintained accordingly.

If the standard values for maintenance are exceeded, maintenance should be planned and carried out. If the danger limit is exceeded, the defect has to be remedied immediately or a speed restriction has to be applied. Standard value for maintenance and danger limits concerning the track position are given in Table 13-34, Table 13-35 and Table 13-36.

Table 13-34: Standard value concerning the track position on standard gauge



Track geometry values	Chord (m)	Standard maintenance value (mm)					Danger limit (mm)		
		v (km/h)					v (km/h)		
		v≤ 80	80 <v≤ 120	120 <v≤ 160	160 <v≤ 230	v≥ 230	120 <v≤ 160	160 <v≤ 230	v> 230
Longitudinal level	2.6/6	12	10	8	6	5	14	11	9
Cross level		10	8	7	6	5	11	10	9
Versine	4/6	12	10	8	6	5	14	11	9
Track gauge		+20	+10	+10	+8	+5	+25	+20	+15 -4

Table 13-35: Standard maintenance value for rail surface defects on standard gauge

Type of defect	Wavelength range (mm)	Standard maintenance value (mm)	Max. admissible (mm)
Corrugation	10-100	0.05	0.15
Short waves	100-300	0.1	0.3
Long waves	300-3000	0.4	-

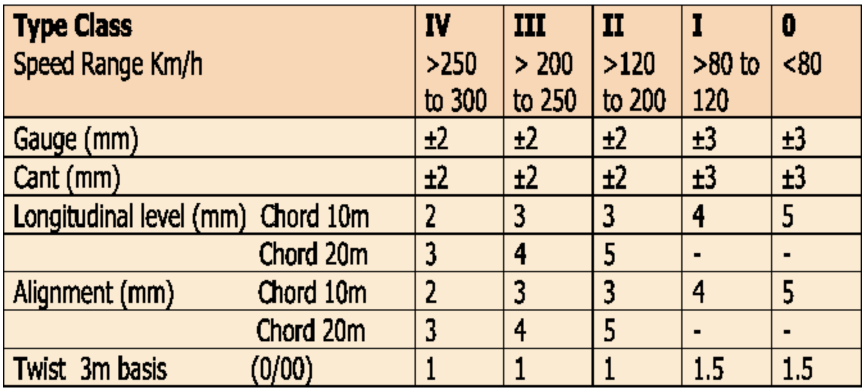
Table 13-36: Standard maintenance values – cross profile of the rail head

V (km/h)	Admissible radia deviations (mm)
120 < v < 140	+ 1.5
140 < v < 160	+ 0.7
> 160	+ 0.5

13.2.7.4 Accuracy of acceptance

After maintenance the track geometry has to meet the following requirements:

Table 13-37: Maintenance Tolerances for high speed corridor



Type Class Speed Range Km/h	**IV** >250 to 300	**III** > 200 to 250	**II** >120 to 200	**I** >80 to 120	**0** <80
Gauge (mm)	±2	±2	±2	±3	±3
Cant (mm)	±2	±2	±2	±3	±3
Longitudinal level (mm) Chord 10m	2	3	3	4	5
Chord 20m	3	4	5	-	-
Alignment (mm) Chord 10m	2	3	3	4	5
Chord 20m	3	4	5	-	-
Twist 3m basis (0/00)	1	1	1	1.5	1.5

The following tolerances apply to tracks with marked survey points and have to be observed:
Track level allowance referring to the marking: + 10mm / - 20 mm
Allowed track distance referring to the marking +/- 10mm
Besides, the following tolerances apply:

Sleeper spacing: Loose sleepers	+ 20mm < 5%
Level of track joints (1.5-m basis)	+ 2.0 mm upwards, 0 mm downwards

Table 13-38: Acceptance limits – longitudinal profile after grinding

Type of defect	Range of Wavelengths (mm)	Acceptance limits (mm)
Roughness	< 10	0.01
Corrugation Short waves	10-30	0.01
	30-300	0.02
Long waves	300-1000	0.13
	1000-3000	0.30

Table 13-39: Acceptance limits – cross profile of the rail head

V (km/h)	Acceptance limits (mm)
V < 140	+ 0.7 / - 1.0
140 <= v <160	0.5 / - 0.3
V >= 160	0.3 / - 0.3

13.2.7.5 Existing Track Tolerances in IR

The track tolerances for operation of passenger trains at a maximum speed of 160 km/h with WAP3 locomotive on Mark-IV bogie and coaching stock with IR-15 bogie coaches has been done by RDSO is described Table 13-40.

Table 13-40: Proposed track tolerances for high speed route corridor

Track Parameter	Standard Deviation	Maximum peak Exceedances
Unevenness (Base 9.6m)	5.0 mm	15 mm
Alignment (Base 9.6m)	3.5 mm	10 mm
Twist (base 4.8m)	3.0 mm	09 mm
Gauge	2.3 mm	08 mm

Track Parameter	Standard Deviation	Maximum peak Exceedances
Unevenness (Chord 40m)	3.00mm	5mm
Alignment (Chord 40m)	2.00mm	5mm
Twist (base 4.8m)	2.0mm	5mm
Gauge	2.00mm	5mm

13.2.7.6 Ballast Cleaning:

The ballast has to be cleaned when the mean value of the specimen measured as undersized particles through a 25 mm square-mesh sieve indicates a contamination of =30 percent in weight.

13.2.7.7 Considerations on the track quality

When the intervention threshold (desirable driving comfort) is reached, the track is tamped, and the standard deviations of track defects decrease. This period is followed by a period of fast exponential growth of the track defect, before it “gets saturated” and shows a linear course of deterioration – this period is approximately 0.5-2 GMT. The rapid decrease of track quality during the first 0.5-2 GMT of operational load is called initial settlement. This rapid initial deterioration can be reduced by controlled settlement using the Dynamic Track Stabiliser.

Subsequently, the defect increased linearly. This linear rate of deterioration finally passes to exponential growth, depending on the operational load and structural design of the track grid. This happens particularly if cleaning is performed too late or in the case of subsoil problems (rising fines etc.). When the ballast gets contaminated, it loses its load-distributing effect. Then the ballast pressure under the sleepers and the pressure on the subsoil is increased and the effect of tamping does not last. At the same time the achievable initial quality decreases.

13.2.7.7.1 The initial quality

The higher the initial quality, the higher the wear reserve and the longer it takes to reach the intervention threshold again.

The Figure 13-15shows the development of track quality according to the exponential law for rate of deterioration. A poor track (upper limiting value of the scatter) has a low achievable initial quality. The figure shows that the quality of a poor track deteriorates rapidly, that its position cannot be maintained even by repeated tamping but decreases faster and faster.

The typical maintenance cycles for such tracks are between 0.5 – 1.5 years. High rates of deterioration can be found for tracks with a contaminated ballast bed, poor subsoil conditions, or for tracks where the structural design has not been adapted to the operational loads, High-speed tracks or main tracks with high bearing capacity of the subsoil (with sufficient track formation and frost protecting layers) show lower rates of deterioration – these correspond to the lower limiting line of the scatter.

The initial quality of such tracks is high, their rate of deterioration is low, an unchanged, good and durable track position can be reached for long periods by tamping. The typical maintenance cycles for such good tracks are more than 5 years.

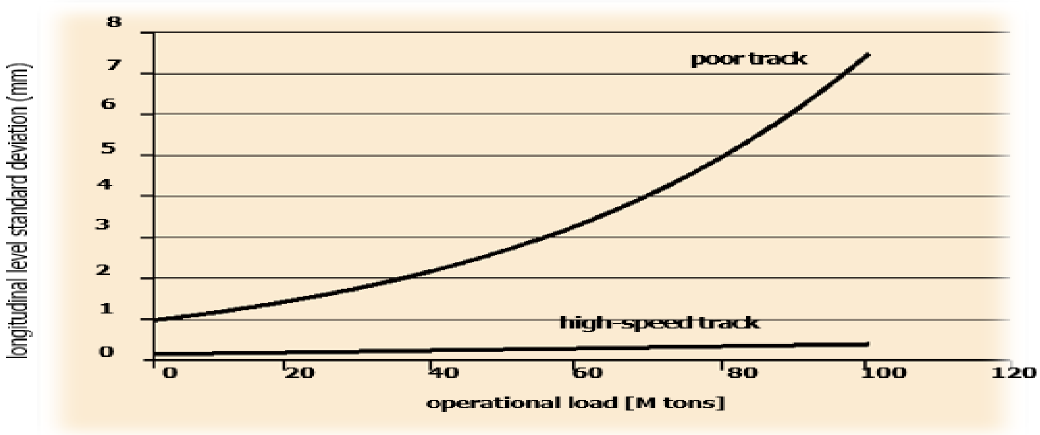


Figure 13-15: Development of track quality depending on the rates of deterioration

Studies have shown that the position of a good track can be improved more in comparison to a rather poor track. The condition and high standard of high-quality tracks with good track position can be maintained more easily and economically than poorer tracks. The higher the initial quality of the track after laying, reconstruction or maintenance, the lower the subsequent maintenance cost. A precise geometric track position significantly influences the initial quality of the track.

13.2.7.8 Track Geometry Measurement through transfer function for high speed track

Versine measurement system are linear and of invariant location. Their specific property is that for periodic defects in track position they generate in their turn periodic signals of the same frequency, but of different amplitudes and phase position.

This means that in a measurement with an asymmetrical 15-m chord (with a division relation 1:2), e.g., a long-wave defect of 70m wavelength and a maximum amplitude of 10mm is shown only with an amplitude of 3.5mm and a phase displacement of 8.5 (or a imaginary displacement of the maximum by 1.6m). This behaviour is described mathematically by the so-called transfer function of the versine measurement system.

13.2.7.9 High Speed Recoding Car

High-speed track recording cars for high-speed lines are equipped with contactless inertial measuring system which allow long-wave track defects to be assessed in accordance with their amplitudes. Apart from the relative exactness of the track position, which is expressed by standard deviation of the measured parameter, it is necessary to record the track position absolutely in order to assess its safety in regard to track buckling.

Therefore, high-speed lines are usually surveyed tracks. The distance and the level of the track referring to fixed or reference points are monitored.

A track recording car has to record defects according to the state of the art and as far as possible in accordance with amplitudes and phases. The range of possible wavelengths, which differ from parameter to parameter, is between mm and 100m. The measured amplitudes are within the range from mm to m. Nowadays, recording cars are produced for a range of measurement speeds between 5 km/h and 250 km/h.

13.2.7.9.1 Multifunctional recording cars

There are many advantages of simultaneous measuring and recording of various track parameters.

In order to ensure efficient maintenance and planning of track reconstruction, railway apply the method of interdisciplinary cooperation between various fields. Track work is increasingly performed in a coordinated way to ensure a minimum of operational hindrance.

Therefore, it seems obvious also to carry out the recording of the individual parameters, which are important in several areas, simultaneously and with the same recording vehicle. Furthermore, this simultaneous approach offers the advantage of putting greatly varied track defects into correlation with one another in order to detect interactions. A defect in track level could, e.g., be connected to a increased wear of the overhead line. As the costs for the use of a recording car are about the same for the measurement of one or of several parameters, it is obvious that the economic efficiency increases with the number of parameters measured at the same time. Multifunctional recording cars offer the additional advantage that all measured parameters are correctly listed in real time for each location.

13.2.7.10 Measured parameters and marginal conditions

13.2.7.10.1 Permanent way parameters

Table 13-41 shows a list of the parameter which are relevant for permanent way and marginal conditions according to the state of the art.

Table 13-41: Relevant parameters for permanent way

Measured value	Wavelength (m)	Type of measurement	maximum recording speed (km/h)
Longitudinal level	1-100	Contacting; Contactless; inertial	250
Position / long wavelengths	1-100	Contactless; inertial	250
Absolute position	-	Contactless GPS	250
Versine	1-15	Contacting, contactless, calculated	250
Superelevation	-	Contacting, contactless, inertial	250
Twist	-	Contacting, calculated	250
Track gauge	0.25-100	Contacting, contactless, under load	250
Track gaps (joint gap, diamonds)	0.5-1	Contactless, image evaluation	160

For contact measurement, measuring wheels or sensors are used. Contactless measurement uses optical laser-aided triangulation measurement device, but also later scanners, video-systems with image evaluation, and inertial measurement system.

The absolute position of the recording car can be determined during the run by using the DGPS (Omn/STR – European service for GPS correction signals). So, nowadays, the position may be determined with an exactness of upto 0.5-1m.

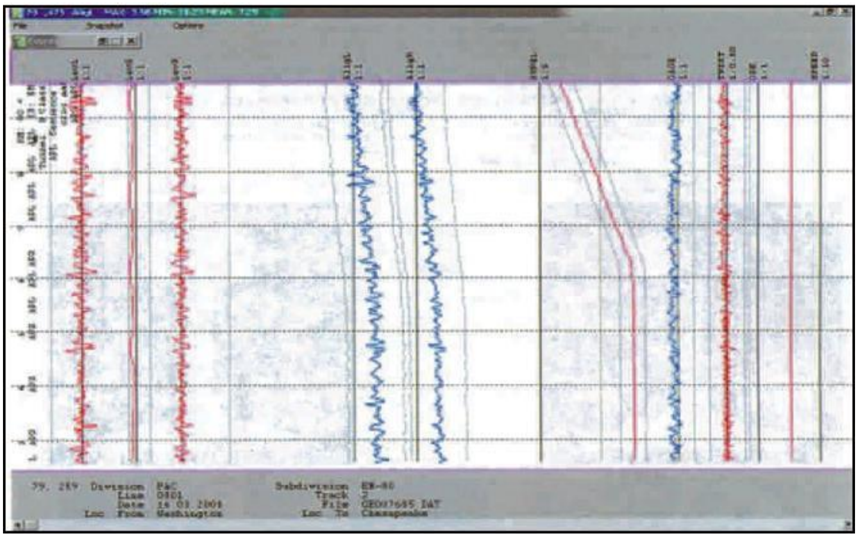


Figure 13-16: Monitor image of recorded track geometry

13.2.7.10.2 Subsoil parameter:

Nowadays, subsoil properties, like water content, statements on the layer structure, etc., can be recorded continuously only by georadar. The measuring speeds are restricted to 30-50 km/h.

13.2.7.10.3 Ballast parameters:

At the moment there are only contactless measurement systems which measure the ballast bed profile by using scanners. The thickness of the ballast bed can be determined by using georadar.

13.2.7.10.4 Rail measurement:

Table below shows a list of track parameters which can be recorded, as well as its marginal conditions according to the state of the art.

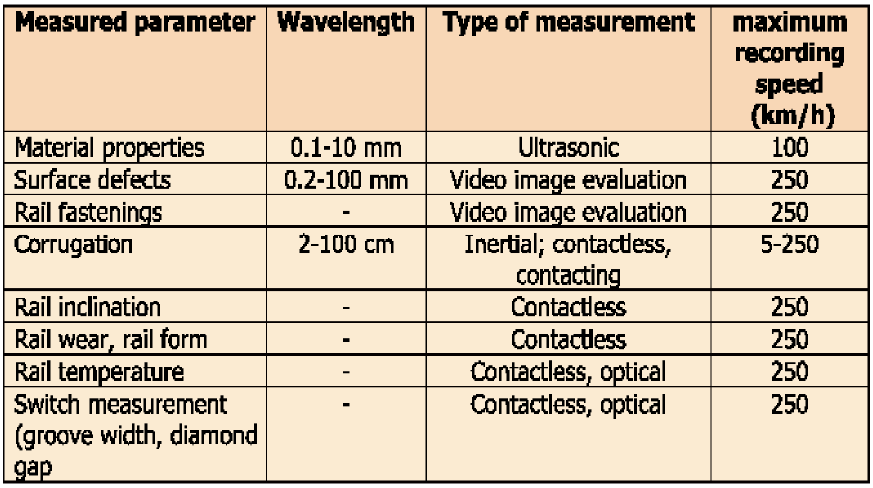
Video imaging and high-resolution fast digital cameras can automatically recognize and evaluate defects of the rail surface and of the rail fastenings.

Corrugation measurement is performed by inertial measurement using a softly sprung mass on which a laser distance measurement device is installed. The measurement signal of corrugation is of much higher frequency than the natural vibration of the system.

The rail profile is measured by illuminating the rail head through a laser slot and recording it digitally, usually stereoscopically. The measured rail profile is determined by comparing it to stored target profiles.

Subsequently, the measured actual profile is compared to the target profile to calculate the rail had wear. With the help of these digital photographs it is also possible to determine the rail inclination and track gauge. There are also adapted systems which are able to determine the groove width and the diamond gap of switches.

Table 13-42: Rail Measurements



Measured parameter	Wavelength	Type of measurement	maximum recording speed (km/h)
Material properties	0.1-10 mm	Ultrasonic	100
Surface defects	0.2-100 mm	Video image evaluation	250
Rail fastenings	-	Video image evaluation	250
Corrugation	2-100 cm	Inertial; contactless, contacting	5-250
Rail inclination	-	Contactless	250
Rail wear, rail form	-	Contactless	250
Rail temperature	-	Contactless, optical	250
Switch measurement (groove width, diamond gap	-	Contactless, optical	250

13.2.7.11 Measurement of the overhead line

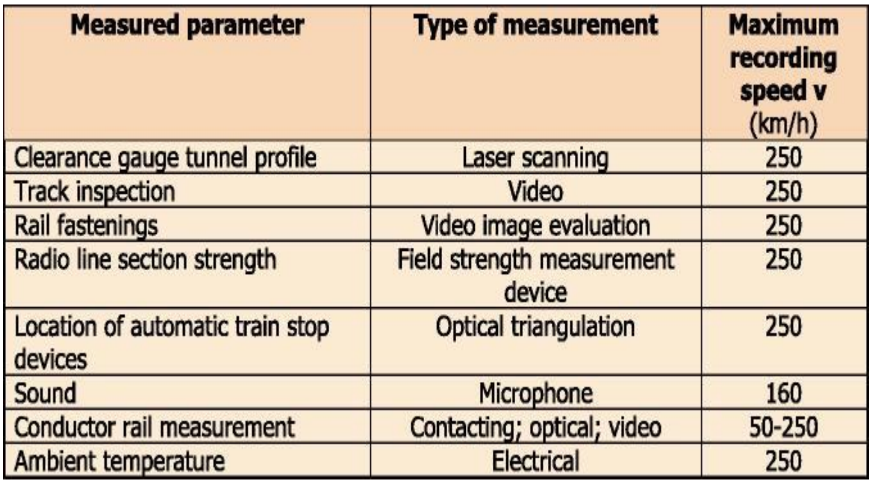
Please refer the Electric traction maintenance plan section.

13.2.7.12 Measurement of the track surroundings and track inspection

Table below Shows a list of the parameters which can be recorded during a measurement of the track surroundings, as well as their marginal conditions, according to the state of the art.

Colour video systems which record the railway track and its surroundings exist for track inspection purposes. The exact location of each individual video image can be identified by superimposition of the current position data. Thus, the system can provide general information on the track structure, the ballast bed, the vegetation, the catenary, tunnels and bridges, etc.

Table 13-43: Parameters of track surroundings and track inspection



Measured parameter	Type of measurement	Maximum recording speed v (km/h)
Clearance gauge tunnel profile	Laser scanning	250
Track inspection	Video	250
Rail fastenings	Video image evaluation	250
Radio line section strength	Field strength measurement device	250
Location of automatic train stop devices	Optical triangulation	250
Sound	Microphone	160
Conductor rail measurement	Contacting; optical; video	50-250
Ambient temperature	Electrical	250

Other video inspection systems with subsequent image evaluation determine defects of the sleepers and rail fastenings. Images showing defects are classified and stored together with track data and kilometric data.

13.2.7.13 Multifunctional recording car UFM 160

The UFM 160, Figure 13-17 shows a modern version of a universal recording car.

This vehicle was built for use in the German Federal Republic, the Netherlands and Great Britain. It is a recording car consisting of two vehicles. Both vehicles are connected to each other via a passage. The recoding car runs on four pneumatically cushioned bogies, a special development of Plasser & Theurer for speeds of up to 200 km/h. The bogies are equipped with disk brakes, antiskid and antislip systems. Two bogies are powered and ensure a self-propelled running speed and measuring speed of 160 km/h. The drive unit consists of two low-emission 12-cylinder underfloor diesel engines with an output of 550 kW each, two hydrodynamic turbo-gearboxes and two axle gearboxes each.

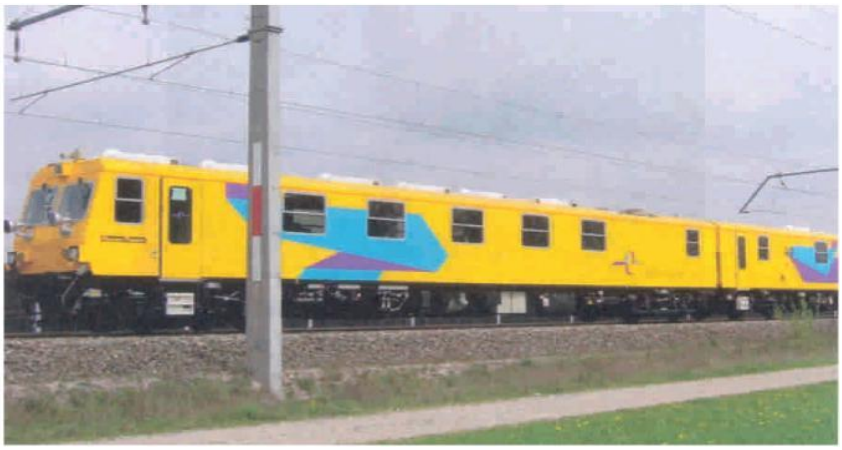


Figure 13-17: Two-piece multifunctional recording car UFM 160

The following are the essential recording systems:

- Measurement of the track geometry parameters with inertial measurement systems, GPS and 2 optical track gauge measurement systems. Measurement and recording of track gauge, super-elevation, longitudinal level, alignment, cross level and track twist,
- An additional rapid track gauge measurement system working according to the laser method of dissecting (allows track gauge to be recorded also for switches in the area of the check rails),
- GPS (OmniSTAR) location and orientation system,
- Rail profile and rail wear measurement system,
- Inertial corrugation measurement system with automatic rail centre follower device,
- Video analysis of the rail surface and the rail fastenings,
- Measurement of the horizontal position and the level of the overhead line,
- Adjustment and measurement of the pantograph pressure,
- Measurement of the position of the masts,
- Measurement of the track surroundings by four high-resolution digital colour video cameras and one high-resolution bland-and-white digital video camera-recording on four digital tape recorders,
- Measurement of the vehicle body acceleration,
- Detection of automatic train stop magnets, and
- Ambient temperature measurement.

13.2.7.14 Small devices for track geometry measurement

Apart from large self-propelled recording vehicles smaller systems exist which are moved along the track by hand. These devices can record the vertical profile, super elevation, versine and track gauge. The vertical profile is recorded via a symmetric versine measurement for the left-hand and right-hand rail (chord length:1 m) and additionally via an inclinometer recording the absolute level in a longitudinal direction. Super elevation is recorded by an additional inclinometer fitted in a transversal direction. The maximum measurement speed of these devices is usually 5 km/h (75 kg dead weight of the device). Such systems are advantageous when the track condition has to be recorded after accidents, to remedy individual defects and, in general, in all cases where the use of an electronic track recording car does not make sense for time or economic reasons.

13.2.7.15 Surveyed track – measurement and calculation of track correction Values

The DB AG, the OBB, the SBB, the SNCF, the RENFE, the FS and railways of other countries survey fixed geodetic points along their tracks.

Stable reference points are marked on both sides of the track at the distance of the catenary masts (Figure 13-18).

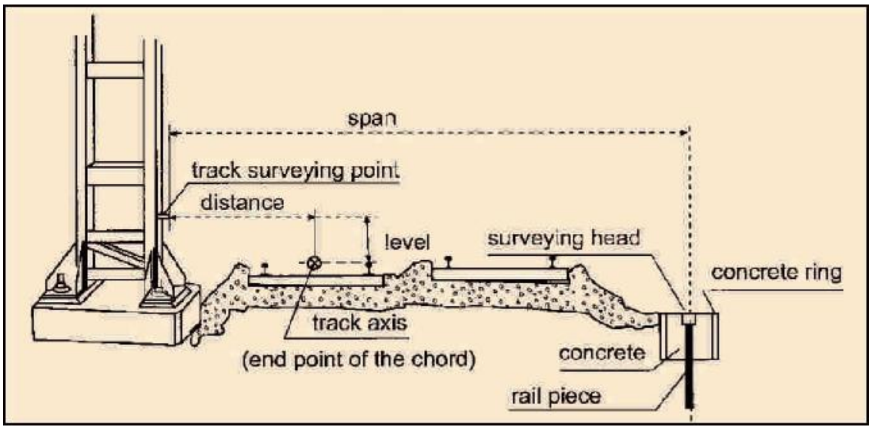


Figure 13-18: Principal sketch of track survey points

13.2.7.15.1 Track surveying car EMSAT

The EMSAT measurement system has proven a success in practical use since 1990.

As the EMSAT uses mechanized measuring methods as against the common manual-optical method, a cost saving by more than factor 5 is achieved.

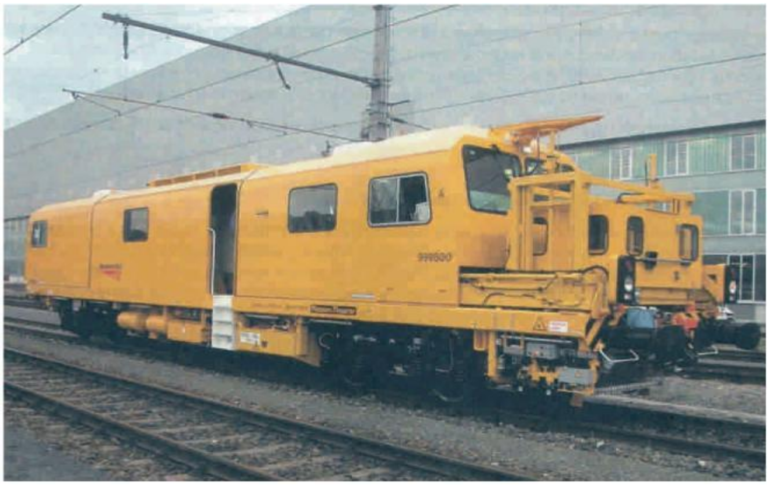


Figure 13-19: EMSAT (Network Rail) with on-track laser satellite

The EMSAT is used for:

- planning and determination of tamping and lining sections,
- surveying for subsequent tamping,
- surveying for the elimination of individual defects by an individual-defect-tamping machine,
- measurement during track reconstruction (checking the laid track in level and alignment) before and after the tamping / lining operations, and
- acceptance of newly built tracks in order to determine whether long-wave defects exist.

The EMSAT continuously detects particularly long-wave track defects in level and curvature (alignment). The resulting actual values are documented for technical and economic purposes in a record (analog chart) referring to target geometry and made available to the tamping machine for further processing.

Long-wave track defects are defects in track level and curvature (alignment) with larger wavelengths upto 250m.

The advantages of an EMSAT measurement compared to manual surveying are its high precision and measuring speed, the measurement and detection of long-wave defects on the basis of an extended chord, the detection and possible elimination of changes in position and level of the existing geodetic points, the high reliability of data without a media break (through data flow), safe working places for the crew where dangers deriving from railway operation are avoided.

Description of the track surveying car EMSAT:

- The EMSAT determines alignment and longitudinal level referred to an extended measuring base), a stationary laser chord,
- It determines superelevation and cross level by an inclinometer,
- It determines the curve length covered between two measurements by measuring wheel, i.e. distance, and
- Measures the track gauge with a measuring axle.

Working range and measuring accuracy:

Working range:

alignment versines: max 1000 mm
longitudinal level versines: max 400 mm length of the laser chord: max approx. 250 m

measurement output: 1.3-2.6 km/h, depending on the length of the laser chords

Measurement accuracy:

versine: 1 mm repeating accuracy

mutual cross level: 1 mm

track gauge: 1 mm

distance measurement: 0.1 m/100 m

The EMSAT is available with an additional 8-channel measurement recorder and geometry measurement equipment (measuring chord with mechanical measuring axles). Due to this additional measuring and recording equipment track geometry can be documented analogously to the tamping machines.

Use of the EMSAT for track and switch renewal:

The EMSAT is also used for track renewal. Here, the described measurements are performed immediately before the passing of the tamping machine.

For tamping of newly laid track the measurement is performed immediately before the tamping machine passes.

13.2.7.15.2 Description of the Fixed-point Measurement Device

The fixed-point Measurement Device is used to exactly determine the absolute track position, i.e. to determine the values of track lifting and displacement in the area of geodetic points (markings by bolts, of bottoms of curves, by pegs etc.).

This device is a combination of an electronic tachymeter for infrared distance measurement and angle measurement and a precision inclinometer for superelevation measurement. The frame is an aluminium light-gauge construction and can be easily and rapidly dismantled into three part. Therefore, the device can be transported in any common passenger car and operated by one person. The device is equipped with a micro-controller with report printer and data storage card for the evaluation of the measured values.

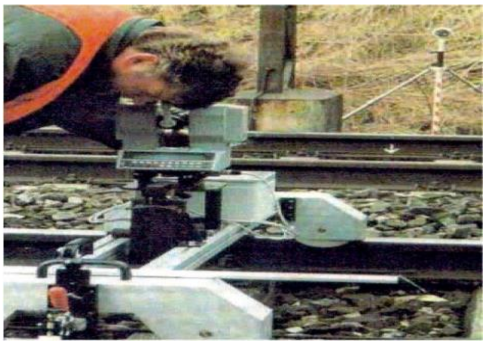


Figure 13-20: Electronic fixed-point measurement device

Working range and measuring accuracy of the fixed-point measurement device:

Working range:

Distance measuring device: $\geq$ 1.3 m

Measurement output: 1.1-2.6 km/h depending on the distance of the geodetic points and the purpose of the measurement (actual track position/span)

Measurement accuracy:

(for individual close-range measurements, according to the manufacturer):

level measurement:	1-3 mm (1.5 m – 5 m)
distance measurement:	1-3 mm (1.5 m-15 m)

The use of the EMSAT in switches: The EMSAT and the Fixed-point Device can be used for checking the outer geodetic points in switches and switch connections.

13.2.7.15.3 Measurement evaluation and decision on necessary measures

The contractor makes the true-to-scale graphic record (measuring chart) of lifting and slewing value including cross level, which is made up by the computer system, available to the network operating organization which then determines the required measures to be taken. The operating organization of EMSAT offers technical advice. After an evaluation of the date the network operating organization chooses the start and end of tamping in such a way as to ensure a harmonic transition to the untreated sections in track level, as well as in curvature (alignment).

A zero lifting value can be accepted at high points, if the slew in this area is small and the deviation of cross level is < 5 mm. In such a case a ramp with a gradient of 1:2000 is built for cross level.

13.2.7.15.4 Transmission and storage of measurement documentation

The contractor of the tamping works is given the target geometry values, the lifting and slewing values, as well as the nominal distance and the nominal level referring to the geodetic points on a data carrier (e.g. CD/DVD/Pen Drive).

Furthermore, he is given a digital printout of the lifting and slewing values, so that he can use them, if necessary, for manual control of the tamping machine (in case the computer system should fail).

13.2.7.16 The GPS satellite measurement technique for the measurement of surveyed tracks

Nowadays, the Global Positioning System (GPS) offers new opportunities for measuring the current track position. Track construction usually requires accuracies which may be achieved only in relative mode (i.e. by reference like measurement).

The GPS allows relative position accuracies of approximately max. +6 mm to be achieved. The accuracy of the level measurement is lower by a factory of 1.5-2. GPS is too inaccurate to replace laser long chord measurement.

However, the GPS offers the economical solution of transferring high-precision local laser long chord date to absolute coordinates.

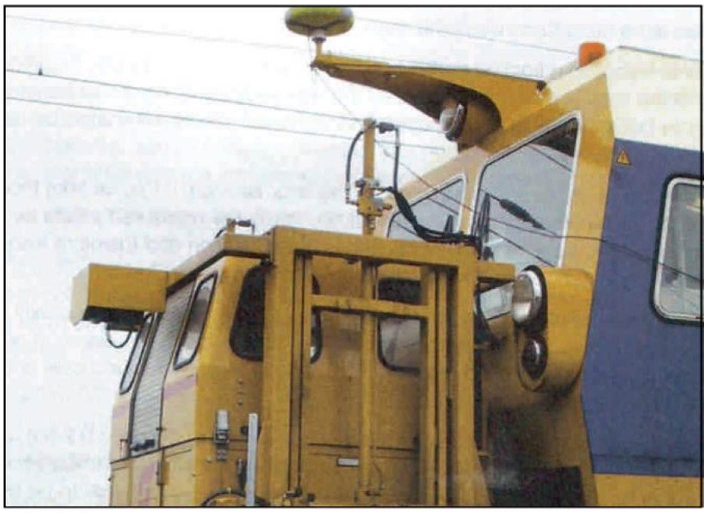


Figure 13-21: GPS aerial on the roof of the EMSAT

13.2.7.16.1 Application of the combined EMSAT-GPS system

The actual track is measured by long laser chords ad at the same time by GPS, which enables the long laser chord (operating in a local system of coordinates) to be determined by absolute coordinates and the high-precision relative data of the long laser chord to be transformed to absolute coordinates.

13.2.7.16.2 The combination of the EMSAT with a Ballast Profile Measurement system

The actual ballast profile on the spot is a significant parameter for the planning of the practicable lifting values on the basis of measured lift correction values. The contactless Ballast Profile Measurement System determines an excess or deficiency of ballast.

13.2.7.17 Automatic guiding computer WINALC for tamping machines

The geometry guiding computer WINALC has to guide the permanent-way machines through the existing track geometry. Therefore, the device has to offer the possibility of entering the target geometry data by hand via keyboard or from a CD. The geometry-dependent correction values for the measurement and control systems of the machine have to be calculated. Unknown target geometry has to be measured, optimized and transferred to the track as a new target position. The displacement limits in constraints (bridges, level crossings) and reference points, as well as preset minimum lifting values, have to be taken into account.

The system has to offer the possibility of storing and printing the results of the measurement records and the optimization calculations. A desirable feature is the recording of the geometric position reached while the tamping machine is working. This offers the opportunity to train the personnel in the office, to prepare geometry data in the office and to transmit them on floppy discs to the geometry guiding computer of the tamper.

Functions of the WINALC

Entry of target geometry data:

The target geometry data (radii, length of transition curves, shape of transition curve, ramps, changes in gradients, super elevation, etc.) are entered into a WINALC table, and this entry is immediately represented graphically. The target track geometry data can also be entered and modified in a graphical representation mode. The modification of a geometry element can be made by mouse-clicking the corresponding element; the parameter is then changed in the window that appears.

Electronic versine compensation and track geometry optimization:

In this working mode an existing track position is recorded during a measuring run of the working machine. It measures versine values for alignment and level, as well as super elevation (via inclinometer), represents them graphically and stores them.

This measurement is the basis for an optimization of track geometry which smooth the course of versines for alignment and level. The correction values (displacement and lifting values) are calculated from this smoothed curve by comparing its values to the measured actual versine. Smoothing and calculation are carried out in an automatic process. The operator can set the following line 0 classes:

0	(up to 80 km/h)
1	(80-120 km/h)
2	(120-160 km/h)
3	(160-300 km/h)

Standard deviations for a compensation length of 35 m for the track classes 0-3 are defined in the programme. Furthermore, standard deviations for a compensation length of 70 m are defined for the track classes 2 and 3. during optimization, the programme continue the smoothing process, until the value remain below the pre-set standard deviations. Apart from the track class, the operator also has to enter the constraint conditions of the line section.

The entire calculation procedure is started at the touch of a button and performed automatically; no interaction of the operator is required.

It is possible to carry out track measurement while the machine is transiting to the work site, after optimization has been carried out the machine will start tamping in this case beginning from the end point of measurement. This is a way of saving the run back to the starting point of measurement. Wavelengths of upto 100m were recorded correctly.

13.2.8 Signal Maintenance Plan

Adequate maintenance procedures must be adopted for each component of the system in order to guarantee very high performance of the high-speed railway system during its whole life. These procedures have to be extended to cover all the Signalling

& Train Control, Communication and Ticketing & Fare collection system sub- systems and other equipment etc.

The maintenance of these systems will consist of basically monitoring of their functioning and taking corrective action whenever a fault is detected. The routine inspection and maintenance as per schedule recommended by the original equipment manufacturer (OEM) will be carried out for the systems.

The recommended system for a SilverLine Corridor requires the following main system/sub-system:

- For Signalling & Train Control System
    - ETCS level-2 System with LTE (Mobile Radio System)
    - Interlocking System (EI/CBI)
    - Electric Point Machine
    - Track Vacancy Detection system (Axle counter)
    - Automatic Train Supervision (ATS)
    - Operation Control Center (OCC) with backup OCC
    - Fall-Back Block System (with line side signal).
- For Communication system
    - LTE System (Mobile Radio Communication System)
    - Backbone Transmission Network (with SDH & GbEN)
    - Telephone system (IP PBX exchange system)
    - Centralised Digital Recording System (CDRS)
    - Passenger Address System (PAS)
    - Passenger Information and Display System (PIDS)
    - Time Distribution System with GPS system
    - Closed Circuit Television System (CCTV)
    - Facility -Supervisory Control and Data Acquisition (F-SCADA)
- For Ticketing and Fare collection system
    - Central Computer System (CCS)
    - Smart Card (EMV based)
    - Mobile Apps/ Mobile Application
    - Station Computer System (SCS)
    - Ticket Office Machine (TOM)
    - Ticket Vending Machine (TVM)/ Self- Service Ticketing KIOSKS
    - Mobile Ticket Counter (MTC)
    - Portable Processing unit (PPU)
    - Automatic Gate (AG)

13.2.8.1 Maintenance Requirement

The requirements for operation and maintenance have to be considered at the early stage the of project, in order to achieve high level of performance of system during the operational stage. The maintenance required in the following phase/ stage of project as:

13.2.8.1.1 Maintenance requirement during design phase

The operation of high-speed lines demonstrates that adaptations of the infrastructure posteriori are more expensive than during the construction of the line. We highlight some measures which must be taken into consideration before the development of the project of a high-speed line. They should be completed or adapted based on local needs and circumstances and on the specific organisation of the envisaged maintenance.

Accesses to the infrastructure: Accesses to the different parts of the line shall be provided; they should be situated close to “significant points”. Optimising these accesses can have a positive effect on the access time of the maintenance staff, the access of rescue services and that of employees of the operating companies. The location of accesses depends largely on the type of substructure (embankment, cutting, at grade, bridge, and tunnel), the chosen maintenance model, the type of resources/equipment to be used, etc.

13.2.8.1.2 Maintenance requirement during construction phase

The quality of a high-speed line and the degradation of the quality of most of the subsystems depend largely on the initial quality of these subsystems after construction and on the care taken to maintain the initial quality in the period of pre-operation and during the first months of operation. The best way to ensure very high construction quality is to establish an active collaboration between the builders and the maintainers of the system.

13.2.8.1.3 Maintenance requirement during testing phase

Special attention shall be paid to all interfaces; generally, the interfaces cause difficulties during tests and at the time of initial operations. Participation of maintenance staff in construction is the best way of training such staff and prepares them in taking over responsibility with respect to maintenance and repairs in case of disruption.

Nevertheless, it is only a preliminary step in the awareness needed to achieve process-driven, computer-supported work.

Before opening the line, a number of tests are to be performed; in this respect, please refer to the requirements of the different specifications for interoperability contained in “Guidelines for homologation of high-speed lines” published by the UIC and the specific requirements of the contract.

Indeed, these tests are done during a period of stabilization of the construction and its components. Unexpected defaults due to differential settlements or due to the dynamic forces of the high-speed test trains may occur.

In case of any defaults, measures to repair them must be taken immediately to avoid further degradation of the subsystem.

13.2.8.2 System Maintenance

The people responsible for design, construction and maintenance of a Semi high speed line (SHSL) have to satisfy various requirements concerning reliability, availability, maintainability, safety and security by seeking:

- To minimise coincidental defaults by the design of the infrastructure and considering the results of the RAMS studies,
- To minimise systematic defaults by applying a strong Quality System,
- To maximise safety by developing a risk management system,
- To maximise the performance of the system by reducing train delays,
- To maximise the availability of the system by reducing the number of hours of possession of the line,
- Methods to permit rapid recovery from disruption.

Preference will be given to incremental/evolutionary improvements rather than revolutionary improvements. These objectives can be achieved by effective managing maintenance and implementing clearly identified procedures:

- To guarantee the safety of the system and the reliability and availability of its infrastructure,
- To ensure highly adequate maintenance with a brief response time at an optimal cost,
- For establishing an extended data- base to ensure accurate analyses to assist in the
- Planning and selection of a specific type of maintenance be it on a short, middle or long-term basis,
- For asset management issues/requirements.

In order to achieve high level of performance of system assets economically and efficiently, process of management review and continuous improvement of system maintenance must be adopted. Information regarding all systems should be kept and updated in centralized monitoring maintenance system. The centralized maintenance system should be installed in OCC for remote monitoring system.

13.2.8.2.1 Central Maintenance Control Center (CMCC)

The remote Maintenance Diagnosis System (MDS) shall be provided at OCC to allow the monitoring of essential wayside and subsystems equipment. Maintenance Diagnosis System in charge to monitor signalling and communication subsystems & equipment. This system triggers alerts and alarms based on the monitored component health status. This system allows to monitor the system health status and to organize the corrective maintenance as well as pre-corrective maintenance (before the failure occurs). It allows increasing the system availability and thus the reduction of the life cycle cost. This system is deployed in the OCC as well as in the Central Maintenance Control Center (CMCC) (if any) and the maintenance bases. Some of the equipment central computer and remote terminal unit of SCADA will be provided with self-diagnostic facilities for testing and fault detection. It shall be a real time system and allow the data archiving system including, but not limited to, the following records:

- Record all events, alarms, and faults.
- Record upcoming risks, non-conformance and result of investigations
- Record in real time at least all input/out data used by the all subsystems.
- Record spare part material management to ensure easy availability.

13.2.8.2.2 Local Maintenance Diagnosis System (LMDS)

The Local Maintenance Diagnosis System (LMDS) for the systems are the independent system that supports and allows the maintenance personnel tasks in the local mode. The main functions of local maintenance diagnosis system are:

- Storing the necessary information of system for maintenance
- Storing the diagnosis information generated by the system.
- Real time reproduction of sequences in the maintenance record
- Real time reproduction of the diagnosis information.
- Reproduction of diagnosis information stored in the maintenance record
- Send diagnosis information of the Central Maintenance Control Centre (CMCC).

13.2.8.2.3 Spare Part Requirement:

The spare items of each subsystem as per OEM (Original equipment manufacturer) shall be provided at central maintenance store at each depot and local maintenance room on the section. The maintenance team shall be trained in multidisciplinary skills for all systems on section. The maintenance team shall be equipped with fully spare equipment-like cards, modules of each system as requirement for regular maintenance. Maintenance transport vehicle shall be provided to each maintenance team on section with maintenance tool kits.

The central maintenance store shall be managed to all systems and subsystems spare parts/ tools. Also, maintenance lab facility shall be provided at OCC/ Depot or at suitable location on the section. The lab will be equipped for diagnostic and testing of equipment as per the OEM (Original equipment manufacturer) guideline to rectify the faults and undertake minor repairs. For major faults (as per OEM maintenance manuals) in electronics card/modules/subsystem shall be sent to the OEM lab/workshop for replacement/rectification with proper documentation for record. The maintenance team shall be monitored continuously essential wayside and subsystems equipment on section (Depot/ Station/ line side location etc.) to provide the corrective & preventive maintenance on time (before the failure occurs). It allows increasing the system availability and life cycle cost.

13.2.8.2.4 Schedule of maintenance of system

The maintenance of system will consist of basically monitoring their functioning and taking corrective action whenever a fault is detected. The routine inspection and maintenance as per schedule recommended by the original equipment manufacturer (OEM) will be carried out of the systems. The normal schedule different system are as,

Table 13-44: Parameters of track surroundings and track inspection

Subsystem Designation	Frequency	Staff
Train Control System (ETCS)	2 weeks	Engineer +Technical Assistance
Fall Back system	4 weeks	Engineer+ Technical Assistance
OCC systems/ Equipment	1 weeks	Engineer+ Technical Assistance
BCC systems/ Equipment	2 weeks	Engineer+ Technical Assistance
Electronic interlocking system	2 weeks	Technical Assistance
On Board Equipment of ETCS/Radio	1 week	Engineer+ Technical Assistance
Wayside Equipment of ETCS	2 weeks	Technical Assistance
Signalling power supply system	2 weeks	Technical Assistance
Telemetry system	2 weeks	Technical Assistance
Wayside Axle counter	4 weeks	Engineer+ Technical Assistance
Wayside signals	4 weeks	Technical Assistance
Monitoring systems	Daily	Engineer +Technical Assistance
Point machine	2 weeks	Engineer+ Technical Assistance
Power supply system	2 weeks	Technical Assistance
Data transmission system (BTN)	1 week	Engineer+ Technical Assistance
Telephone system	2 weeks	Technical Assistance
Radio system LTE/GSM-R	2 weeks	Engineer+ Technical Assistance
Radio Tower/ Coverage	2 weeks	Engineer+ Technical Assistance

Subsystem Designation	Frequency	Staff
Public address system	1 week	Technical Assistance
Close circuit television	2 weeks	Technical Assistance
Time distribution system	2 weeks	Technical Assistance
Passenger information System	1 week	Engineer +Technical Assistance
FSCADA systems	1 week	Technical Assistance
Indoor equipment of all system	2 weeks	Engineer +Technical Assistance
Automatic gate	2 weeks	Technical Assistance
Ticketing Station System	4 weeks	Engineer +Technical Assistance
TVM/ TOM	2 weeks	Technical Assistance
Tunnel Safety system	2 weeks	Engineer +Technical Assistance
Outdoor equipment	4 weeks	Technical Assistance
Cleaning of Racks	12 weeks	Technical Assistance
Fibre Optics / cables	4 weeks	Technical Assistance
Inspection of line / Depot	4 weeks	Engineer +Technical Assistance

Note: The routine inspection and maintenance of system as per schedule recommended by the original equipment manufacturer (OEM) will be carried out.

The signalling & communication train borne equipment will be inspected in depot. The outdoor equipment require more attention for routine inspection. In case where the repair cannot be carried out at site, the equipment will be brought to maintenance depot workshop for repair. The modular technology will be used in most of the equipment and hence the maintenance will consist of replacing the defect item with new/ reconditioned one or either replacing the defective modular if it is cost effective or better to scrap it.

13.2.8.2.5 Life Cycle of System

Due to increasing performance demands from governments and train operating companies, infrastructure management must optimise the reliability and the availability of high-speed lines. Reliability and availability have an impact on the Life Cycle Costs of the infrastructure and indirectly on the costs and revenues of transport operations.

Even during the development, construction and operation phases, choices must be made on the design, the maintenance programs and – in the long term - the renewal programs. These choices have an effect on the Life Cycle Costs of the system and the various subsystems in achieving an optimal trade-off between investment and maintenance. This chapter provides information about some relevant components of the railway system and comments on the origin of such information.

The availability of a high-speed line is an important factor in the life cycle of the line. This availability has an effect, in case of PPP projects, on the revenue of the concessionaire of the infrastructure and often constitutes part of the contract requirements.

There is, as of the date hereof, no specific definition for the Degree of availability. Various formulas are used to define this requirement. In some contracts premiums or penalties are foreseen as a function of the availability.

Due to rapid advances in the development of electronic devices, the maximum life cycle of electronic components in signalling and communication systems is now 10-15 years. After the first 10 years or so there will be an increasing requirement like replacement and renewal as heavily used equipment falls out due to overhaul and replacement, to prevent deterioration in performance levels. The actual maintenance will be depending on the design of system manufacturer and maintenance team.

13.2.9 Operation and Maintenance Organisation

The SilverLine Corridor O&M organisation is prepared considering the O&M organisation of the different high speed trains and metros. The proposed O&M organisation details are summarised in the Figure 13-22.

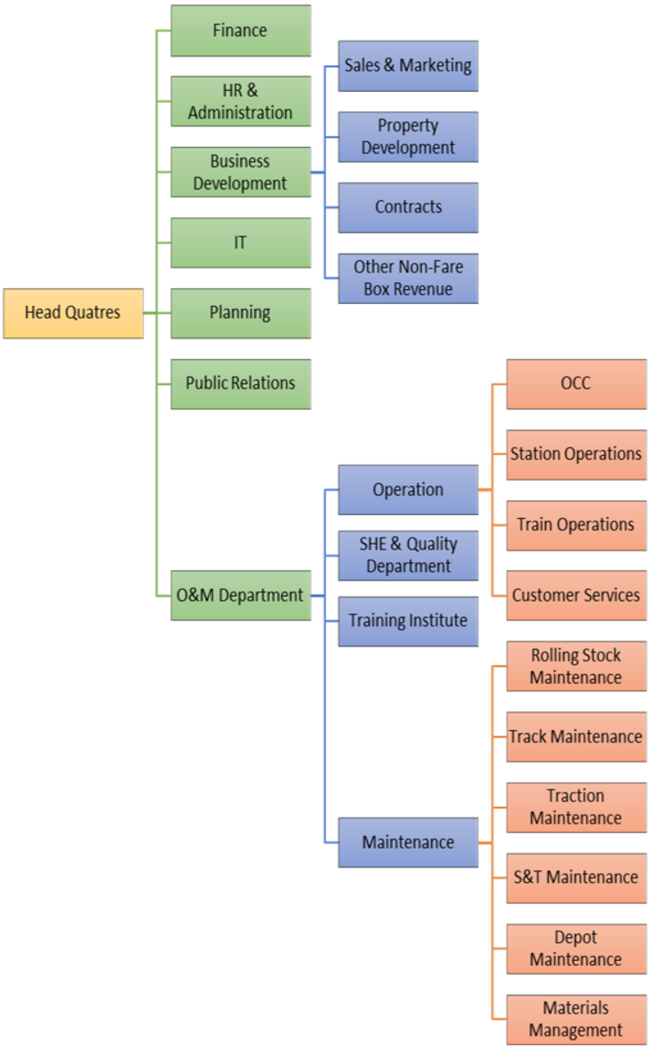


Figure 13-22: O&M Organisation

Based on the above O&M organisation and operational details, the manpower requirement of the O&M organisation has arrived as shown in Table 13-45, required for the revenue operation on 2025. Similar man power per km is adopted in Mumbai-Ahmadabad Corridor and Taiwan high speed corridor.

Table 13-45: Manpower Details

Department	No of Units	In House	Outsource	Total Staff
OCC	1	54	10	64
Training Centre	1	20	2	22
SHE	1	21	0	21

Department	No of Units	In House	Outsource	Total Staff
Station	11	409	792	1201
Train Crew	1	427	10	437
Rolling Stock Maintenance	2	372	116	488
Depot Maintenance	2	81	10	91
DCC	2	19	0	19
Civil & Track Maintenance	6	840	360	1200
Traction & MEP Maintenance	4	480	120	600
S&T Maintenance	4	384	96	480
HQ	1	250	0	250
TOTAL		3357	1516	4873

13.2.10 Safety Plan

13.2.10.1 Introduction

The Rolling Stock shall be maintained with the aim to achieve and to guarantee a defined

One of the primary responsibilities of the SilverLine Rail are to ensure the safe conduct of railway operations. In performing this role, it pays particular attention to the conduct of rail passenger services, in view of the large number of members of the public at risk. Through maintenance of this oversight, and the operational and safety practices used by the passenger rail industry, an excellent safety performance has been achieved, comparable with other common carrier passenger transportation modes.

In semi high-speed railways, to run trains near a speed of 200 km/h, mechanism to ensure train safety is critical. The safety mechanism to ensure safety is broadly based on following concept:

- Selection of facilities and rolling stock to cope with high-speed operation and establish a comprehensively harmonized modern mechanism.
- Elimination or minimization of the human intervention on safety critical elements by technological means or fool-proofing.

- Adoption of highly redundant systems for important safety equipment/ facilities to improve reliability and ensure fail-safe principle is applied comprehensively and followed strictly.
- Take measures to avoid the effect of windstorms, floods, earthquakes and other damages caused by natural phenomena as far as possible.
- Introduce equipment/facilities to minimize accidents due to obstacles falling on track (e.g. automobiles) and other troubles and institute legal/regulatory measures against deeds to compromise the safety of train operation.

13.2.10.2 Safety Plan in SilverLine

The safety measures in SilverLine rail has to be incorporated from the designing of the project itself. The safety measures are to be implemented during construction and operation and maintenance. Main area to be studied to ensure the safety in SilverLine rail is based on the following aspects.

- The interaction between these works and the works of other in close proximity to the railway
- The intended use of the system and the mode of operation
- Maintenance activities
- The relationship between persons, infrastructure and systems e.g. Human factor considerations, disability provisions.
- The wilful act of persons to vandalize
- The interactions between the railway and its neighbours – noise, vibration, EMC and visual impact
- Degraded operating conditions
- Environmental conditions
- Fire prevention and life safety systems in Emergency scenarios

High level of safety shall be provided in SilverLine by incorporating safety measures in the following subsections of the semi high speed rail

1. Rolling Stock
2. Track and Infrastructure
3. Signal and Electrification
4. Operation & Maintenance
5. Emergency Conditions
6. Human Factors

Each of the case is detailed in the following sections with measures ensuring the safety of the passengers and staff.

13.2.10.3 Safety Measures

The sub sections of the SilverLine are responsible for ensuring the collective safety of the lives and assets.

13.2.10.3.1 Rolling Stock

As the moving part and passenger carrying element of the semi high speed rail, Rolling Stock plays an important role in ensuring the safety. The measures used in Rolling Stock are detailed below.

- Structural crashworthiness- The car body and associated components shall be manufactured as per the relevant standards in order to minimise the casualties in the event of an accident. The coupler, driving cab and the bogie to car body connection strengths contribute the safety of the crew and the passenger in case of an accident. The structural integrity of the trains should be maintained in normal operations and provide protection to persons on the train during an accident.
- Braking System- The braking system design shall be failsafe and it shall maintain the stopping distances to meet the braking performances.
- Track- train interaction- The bogie and its integration of wheels and braking system shall follow relevant standards for preventing derailments. The Rolling Stock shall be designed to cater the alignment characteristics such as gradient, curves and cant. The bogie and wheel design shall consider the maximum lateral forces and the offloading of the wheels to avoid the derailments.
- The Rolling Stock shall be designed to limit the noise, vibration and EMC impacts. The design shall follow relevant standards and global practices implemented in other systems.
- The interiors of trains should provide a safe environment for people and their possessions. Trains shall have a safe means of entry and exit including during a train evacuation to trackside situation.
- The train should be provided with an effective means of communication between the driver, train attendant or central controller and the passengers.
- The trains shall be provided with monitoring systems which can monitor the passengers using the train.
- Sufficient fire rating shall be provided to all materials used in the Rolling Stock manufacturing.
- Running capability of Rolling Stock in case fire in Rolling Stock or tunnel.

13.2.10.3.2 Track and Infrastructure

The main measures to be used in track and infrastructure are listed below.

- Track Design- The track shall be designed for maximum stress which are to be developed in both static and dynamic conditions. Similarly, the track shall maintain the quality required for the high speed rail operation. The track and its supporting structure should provide for the safe guidance and support of the train.
- Security of right of way- In view of their long braking distance, it is not possible to for a driver to stop trains to avert obstacles within visual range. Therefore, to prevent people and other obstacles from entering the right of way, high speed railway system is designed as a completely segregated system with grade-separated crossings. Full length of the proposed corridor is proposed to be installed either with compound wall of sufficient height or with suitably designed fencing to prevent trespass and consequent damages. Over these fencing/wall. Solar panels are proposed to be installed to tap solar energy. Alternate designs of compound wall/ fencing available and made are attached for ready reference. Between Southern railways track and SilverLine lines, fencing is proposed to be installed which may be of precast type and easy to install at site and at all

other locations compound wall of any one of the above designs is proposed for construction.

- Prevention of accidents on platform- Platform shall be designed with adequate width to avoid passenger falling on track or contacting trains. Trains shall not pass the platform tracks at high speed to prevent passengers from falling onto the track pushed by the train draft. Through trains shall pass stations via tracks away from platforms unless special provisions are made, and safety is assessed and ensured otherwise.
- The railway system should be protected against unwanted intrusion and unauthorized access.
- Tunnels and other enclosed structures should provide for the safe evacuation or protection of persons under all emergency conditions.
- Elevated railway routes should provide for the safe evacuation of persons away from danger.
- Any person should be able to identify their whereabouts on the railway system using location identify markers.
- Station platforms and access ways shall be appropriately sized for the volume of people using them, including during degraded and emergency conditions.
- The safety of people whilst moving around the stations including allowance for luggage, wheelchairs, buggies, cycles and the like.
- Railway depots, marshalling yards and sidings should have safe walking routes which minimize the possible contact between trains and persons.

13.2.10.3.3 Signal and Electrification

The main measures to be used in Signal and Electrification are listed below.

- In view of their long braking distance, it is not possible to protect high-speed railway trains by using conventional railway signals. Therefore, SilverLine system requires signalling system with Automatic Train Control mechanism.
- Design of Signalling System- The design of the Signalling system shall consider possible cases of safety breach and shall design to mitigate the safety issues. As there are different types of stocks are to be used in SilverLine corridor, the speed thresholds and braking distances of each type of vehicles shall be considered in design. The vehicle detection system and operator interfaces play vital role in ensuring the safe operation of the SilverLine.
- The signalling system should provide for the safe routing, spacing and control of trains, even in degraded conditions.
- A means should be provided for the monitoring and controlling the persons using the railway.
- The systems used for the guidance, control and communication interface of a train shall be compatible and not give rise to danger.
- Railway workers shall be provided with a means of communication with the railway controllers.
- Design of Electrification System- The OHE shall be designed considering the required electrical clearances. All the subcomponents used in the electrification shall be rated to cater both normal and degraded operating conditions. The

design shall consider the aspects providing power block and grounding of the system during maintenance.

13.2.10.3.4 Operation & Maintenance

Operation & Maintenance plays vital role in ensuring the safety of the passengers and staff. Proper procedures and methods are to be adopted for the Operation and Maintenance activities in order to avoid unsafe conditions.

- There should be adequate clearances for public, trains, infrastructure, and maintenance, both in normal and emergency conditions.
- Segregation of Operation and maintenance work hours- As Trains on SilverLine are running at very high speed, maintenance on right of way and other safety critical systems should be planned when no trains are running. In order to find a schedule to maintain the mainline assets with RORO services and no traffic in both tracks, two approaches are adopted.
    - When RORO services are conducted, the time slot after RORO passing and before next passenger services or other track RORO service is allocated for maintenance. Sections having no trains in the section for more than two hours are allowed to conduct maintenance considering the safety aspect. It shall be noted that last RORO service will start before 00:00 Hrs.
    - To maintain the sections which are not covered in the first point, RORO services may suspend on two days per week. Hence the night-time between last passenger service and first passenger service next day is used for maintenance of mainline assets.

  A pictorial representation of the maintenance time allocated for two scenarios as detailed above is shown in Figure 13-23 and Figure 13-24.

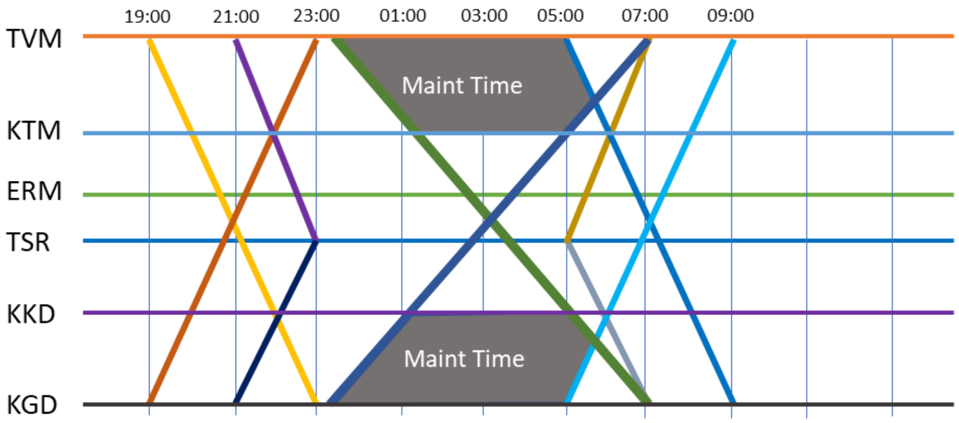


Figure 13-23: Maintenance time period with RORO services

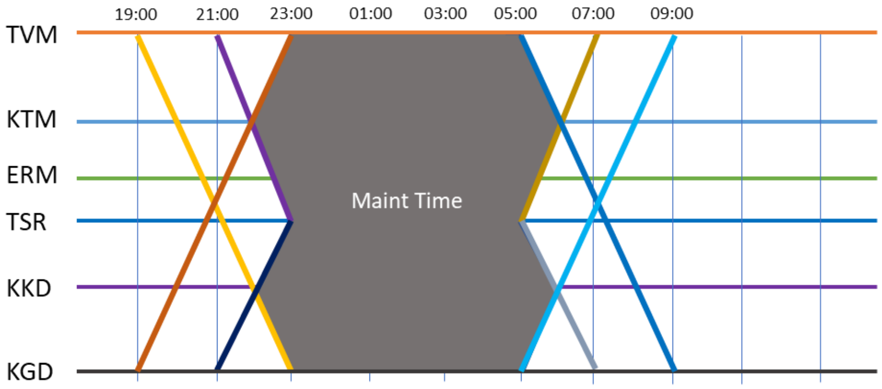


Figure 13-24: Maintenance time period without RORO services

It may be noted that the above time period for maintenance is the end to end maintenance period. Within this period all safety process of maintenance block issue, carrying maintenance activity of the asset and restoration of asset for operation are to be conducted.

- Methods and Procedures- There shall be well defined methods and procedures for carrying out the operation and maintenance activities. Issuing of work order, power block etc shall be carried out with proven methods and procedures. The procedures shall cover the dispatching of trains, brake tests, train crew practices, emergency procedures and the communication procedures etc.
- Maintenance Instructions- All the maintenance activities shall be carried out by following the approved maintenance instructions and maintenance manuals.
- The interaction between road, rail, river/canal, and air and sea traffic should be avoided. Where this is unavoidable then special control measures should be implemented.
- Railway workers should be provided with high visibility clothing so they can be seen both during the days and at night.
- The railway system shall have a safety management system which details the arrangements for providing safe systems of work and safe working environments.
- Each railway operator should undertake a thorough risk assessment and identify how each risk will be controlled.
- The railway should provide for the safe and secure stabling, marshalling and maintenance of the trains.

13.2.10.4 Emergency Conditions

In Semi High Speed Rail, there may be emergency conditions arising because of many reasons such as natural disasters, technical failures, fire, accident etc. This section details about the safety measures to be implemented to cater the emergency conditions safely.

- Prevention and Mitigation of Disasters- The SilverLine is envisioned as Safe and reliable transport system to transform lives of its beneficiaries. However, given the nature ground conditions along the corridor between Thiruvananthapuram to Kasaragod which include unfavourable soil condition, sea-shore related risks, high temperature, heavy rains in the monsoon and uneven terrain, it requires robust foundations and special structures. In structure designing, it is important not only to guarantee stability of track even during earthquake and strength against rains but also to make arrangements to quickly catch meteorological information to prevent occurrence of disaster or minimize damage therefrom, thereby protecting running trains against damage due to natural phenomena. Therefore, introducing a disaster preventing system into this project to automatically collect disaster preventive data is recommended. Terminals of the disaster preventing system will be installed at the operation center and each maintenance depot aiming at establishing a communication system that makes it possible to renew data at a stretch from the operation control center in charge of train operation to field organizations. About rainfall, wind speed & rail temperature, OCC dispatchers check the situation from Disaster Detection and Warning System (DWS), order restriction speed to train drivers and directly send command to high-speed trains. About earthquake, OHE is tripped automatically based on information from distributed seismometers.

- Rescue Operation- Assurance of safety, during normal operation as well as during accidents or disasters, is of paramount importance. Therefore, rescue operation during accidents and disasters shall be planned with adequate arrangements and method to ensure safety. Following method is adopted for rescue in case of accidents or disasters:
    - If the rescue train can come to the accident site, passengers shall be transferred to the rescue train.
    - If the rescue train cannot come to the site, passengers shall get off the train and are rescued from maintenance slopes or emergency stairs.
- The implementation of Fire and Life safety systems must be ensured.
- The choice of materials shall be appropriate to the location and not give rise to danger in a fire situation.
- During an emergency there should be coordinated control between the railway, the emergency services and neighbouring communities.
- Way Side equipment to warn the failure of the different equipment before reaching to an emergency condition.

13.2.10.4.1 Human Factors

Human factors are involved in safety of the SHSR as the train is operated by drives and the maintenance is carried out by staff. The operating and maintaining staffs shall be qualified and trained for the intended activities.

- The Operating and maintenance staff including drivers, other train crew, signal staff and the dispatching staff shall be qualified.
- Proper training at the time of the induction as well during the services shall be provided on time.
- Safety targets and safety monitoring and audit will aim to continuously improve the safety systems and procedures.
- The provision of safety related training to staff, maintainers and operators with appropriate competence assessment should be implemented.

- Those persons who fulfil key safety critical roles such as signallers and track inspectors shall be regularly assessed, refreshed and provided with update training.

13.2.11 Disaster Management Plan

“Disaster is a crisis that results in massive damage to life and property, uproots the physical and psychological fabric of the affected communities and outstrips the capacity of the local community to cope with the situation”. Disasters are those situations which cause acute distress to passengers, employees and outsiders and may even be caused by external factors .As per the disaster management act, 2005 "disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area”. As per world health organisation (WHO): “Any occurrence that causes damage, economic disruption, loss of human life and deterioration of health and services on a scale sufficient to warrant an extra ordinary response from outside the affected community or area”. A disaster is a tragic event, be it natural or manmade, which brings sudden and immense agony to humanity and disrupts normal life. It causes large scale human suffering due to loss of life, loss of livelihood, damages to property and persons and also brings untold hardships. It may also cause destruction to infrastructure, buildings, communication channels essential services, etc.

13.2.11.1 Objectives Disaster Management Plan

The effect of any disaster spread over in operational area of semi high speed rail; is likely to be substantial as SilverLine deals with thousands of passengers daily in underground tunnels, viaducts and stations. Disaster brings about sudden and immense misery to humanity and disrupts normal human life in its established social and economic patterns. It has the potential to cause large scale human suffering due to loss of life, loss of livelihood, damage to property, injury and hardship. It may also cause destruction or damage to infrastructure, buildings and communication channels of Metro. Therefore, there is an urgent need to provide for an efficient disaster management plan. The main objectives of disaster management measures are listed below:

- Save life and alleviate suffering
- Provide help to stranded passengers and arrange their prompt evacuation
- Instil a sense of security amongst all concerned by providing accurate information
- Protect SilverLine Property
- Ascertain the cause of accident
- Expedite restoration of train operation
- Lay down the actions required to be taken by staff in the event of a disaster in SilverLine in order to ensure handling of crisis situation in coordinated manner

- To ensure that all officials who are responsible to deal with the situation are thoroughly conversant with their duties and responsibilities in advance. It is important that these officials and workers are adequately trained in anticipation to avoid any kind of confusion and chaos at the time of the actual situation and to enable them to discharge their responsibilities with alertness and promptness

13.2.11.2 List of Serious Incidents Requiring Disaster Management Measures

SilverLine specific disasters can be classified into two broad categories e.g.: Man-made and Natural.

a. Man Made Disaster
    i. Terrorist attack
    ii. Bomb threat/ Bomb blast
    iii. Hostage
    iv. Release of Chemical or biological gas in trains, stations or tunnels
    v. Fire in metro buildings, underground/ elevated infrastructures, power stations, train depots etc.
    vi. Train accident and train collision/derailment of a passenger carrying train
    vii. Sabotage
    viii. Stampede
b. Natural Disaster
    i. Earthquakes
    ii. Floods

13.2.11.3 Guidelines for Disaster Management

Detailed rules and guidelines are available in both Central level and State Level. Based on these guidelines, the organization of SilverLine shall frame their own disaster management system and disaster management manuals.

1. The National Disaster Management Authority (NDMA)

Establishment of National Disaster Management Authority: -

- With effect from such date as the Central Government may, by notification in the Official Gazette appoint in this behalf, there shall be established for the purposes of this Act (The Disaster Management Act, 2005), an authority to be known as the National Disaster Management Authority.
- The National Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the Central Government and, unless the rules otherwise provide, the National Authority shall consist of the following: -
    - The Prime Minister of India, who shall be the Chairperson of the National Authority, ex officio;
    - Other members, not exceeding nine, to be nominated by the Chairperson of the National Authority.
- The Chairperson of the National Authority may designate one of the members nominated to be the Vice-Chairperson of the National Authority.

- The term of office and conditions of service of members of the National Authority shall be such as may be prescribed.

2. State Disaster Management Authority:
   Establishment of State Disaster Management Authority: -
   - Every State Government shall establish a State Disaster Management Authority for the State with such name as may be specified in the notification of the State Government
   - A State Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the State Government and, unless the rules otherwise provide, the State Authority shall consist of the following members, namely:-The Chief Minister of the State, who shall be Chairperson, ex officio;
     - Other members, not exceeding eight, to be nominated by the Chairperson of the State Authority;
     - The Chairperson of the State Executive Committee, ex officio.
   - The Chairperson of the State Authority may designate one of the members nominate to be the Vice-Chairperson of the State Authority.
   - The term of office and conditions of service of members of the State Authority shall be such as may be prescribed.
3. Railway Disaster Management Authority:
   Every Railway Authority, subject to the supervision of the NDMA and State Authority: -
   - Prepare disaster management plan setting out the following, namely: -
     - Provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
     - Provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
     - The response plans and procedures, in the event of, any threatening disaster situation or disaster;
   - Coordinate the preparation and the implementation of its plan with those of the other organizations at the district level including local authority, communities and other stakeholders;
   - Regularly review and update the plan; and Submit a copy of its disaster management plan, and of any amendment thereto, to the District Authority or State Authority.

13.2.11.4 SilverLine Disaster Management Plan

A detailed disaster management plan has to be framed for the SilverLine before the commercial operation of the trains. The design and implementation of the project shall take care all the measures to mitigate the effects of disasters. The disaster management plan of SilverLine is broadly divided into the following categories:

1. Disaster Mitigation and Prevention
2. Disaster Management Planning and Preparedness
3. Review of Disaster Management

13.2.11.4.1 Disaster Mitigation and Prevention

This stage consists of strengthening the basic infrastructure such as the track, bridges, rolling stock, and signalling equipment as well as introducing systems and procedures to ensure that accidents are minimized, if not prevented. To prevent emergency situations and to handle effectively in case 'one arises' there needs to be following provisions for an effective system which can timely detect the threats and help suppress the same.

- Fire detection and suppression system
- Smoke management
- Environmental control system
- Tunnel ventilation system
- Track-way exhaust system
- Station power supply system
- DG sets & UPS
- Lighting system
- Station area lights
- Tunnel lighting
- Tunnel lighting control
- Seepage system
- Water supply and drainage system
- Sewage system
- Any other system deemed necessary

The above list is suggestive not exhaustive actual provisioning has to be done based on site conditions and other external and internal factors.

13.2.11.4.2 Disaster Management Planning and Preparedness

The successful management of a disaster depends on the ability to foresee and control it in time. Planning is thus vital for minimizing disaster effects, quick recovery, and resumption of work. The key to developing an effective disaster plan is to anticipate every possible vulnerability and taking the appropriate action to tackle the same effectively. In this context it is necessary to identify the available resources and utilize them most efficiently. The duties of various officials should be defined in detail so that work can proceed as per the planned strategy. The management should be fully prepared to face a disaster and should possess a proper action plan for dealing with the same.

Disaster management plan also contains detailed guidelines relating to cases of breach/floods, earthquakes, cyclones, manmade disasters like terrorism etc. It must include management of rescue and relief operations including care for dead, communication network, restoration operations, maintenance of rescue vehicles & their equipment, media management, check list for officers and supervisors etc.

In order to achieve this milestone a detailed disaster management plan and preparedness of disaster management are the pillars.

- Disaster management manual- A detailed manual shall be prepared to cater the disasters occurring. It shall cover the following topics in detail

  - Command, Control and coordination of emergency rescue situations
  - Organization for disaster management
  - Accidents
  - Security threats and terrorist attack
  - Chemical Disaster
  - Natural Calamities
  - Rescue and Relief strategies
  - Crowd Management in mass gathering
- Preparedness of disaster management- Being a technological complex system worked by new set of staff, with a learning curve to improve and stabilize with time, intensive mock drills for the staff concerned is very essential to train them to become fully conversant with the action required to be taken while handling emergencies. They also need to be trained in appropriate communication skills while addressing passengers during incident management to assure them about their wellbeing seeking their cooperation. Since learning can only be perfected by 'doing' the following Mock Drills:
    1. Fire Drill
    2. Rescue of a disabled train
    3. Detrainment of passengers between stations
    4. Passenger evacuation from station.
    5. Drill for use of rescue & relief train
    6. Hot line telephone communication with state disaster management authority

13.2.11.4.3 Review of Disaster Management

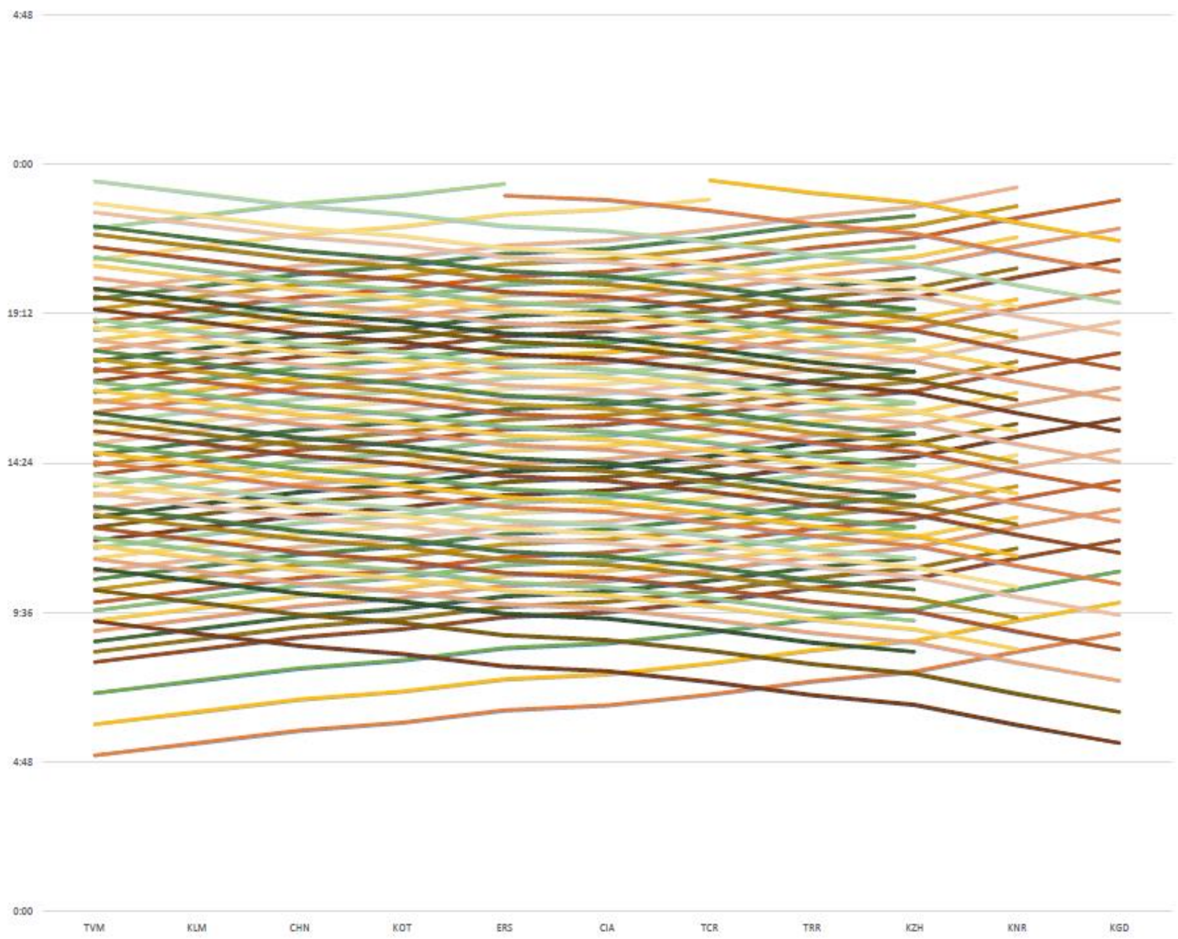
A high-level committee of SilverLine authority has to review disaster management to modernize it based on the past experience and other conditions. The various aspects that would help in the modernization of disaster management are given below.

- Faster response
- Better facilities and equipment
- Expanding resources to meet requirements in major accidents
- Better customer focus
- Training and preparedness

Annexure 1 to Chapter-13- Time Tables

Annexure-1 Time Tables & Charting

		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
UP	TVM	5:00	5:00	6:00	6:00	7:00	7:00	8:00	8:00	8:20	8:20	8:40	8:40	9:00	9:00	9:20	9:20	9:40	9:40	9:54	9:54	10:20	10:20
	KLM	5:22	5:24	6:22	6:24	7:22	7:24	8:22	8:24	8:42	8:44	9:02	9:04	9:22	9:24	9:42	9:44	10:02	10:04	10:17	10:19	10:42	10:44
	CHN	5:46	5:48	6:46	6:48	7:46	7:48	8:46	8:48	9:06	9:08	9:26	9:28	9:46	9:48	10:06	10:08	10:26	10:28	10:41	10:43	11:06	11:08
	KOT	6:02	6:04	7:02	7:04	8:02	8:04	9:02	9:04	9:22	9:24	9:42	9:44	10:02	10:04	10:22	10:24	10:42	10:44	10:57	10:59	11:22	11:24
	ERS	6:25	6:27	7:25	7:27	8:25	8:27	9:25	9:27	9:45	9:47	10:05	10:07	10:25	10:27	10:45	10:47	11:05	11:07	11:20	11:22	11:45	11:47
	CIA	6:35	6:37	7:35	7:37	8:35	8:37	9:35	9:37	9:55	9:57	10:15	10:17	10:35	10:37	10:55	10:57	11:15	11:17	11:30	11:32	11:55	11:57
	TCR	6:56	6:58	7:56	7:58	8:56	8:58	9:56	9:58	10:16	10:18	10:36	10:38	10:56	10:58	11:16	11:18	11:36	11:38	11:50	11:52	12:16	12:18
	TRR	7:21	7:23	8:21	8:23	9:21	9:23	10:21	10:23	10:41	10:43	11:01	11:03	11:21	11:23	11:41	11:43	12:01	12:03	12:16	12:18	12:41	12:43
	KZH	7:40	7:42	8:40	8:42	9:40	9:42	10:40	10:42	11:00	11:02	11:20	11:20	11:40	11:42	12:00	12:02	12:20	12:20	12:35	12:37	13:00	13:02
	KNR	8:19	8:21	9:19	9:21	10:19	10:21	11:19	11:21	11:39	11:39			12:19	12:21	12:39	12:39			13:14	13:16	13:39	13:39
	KGD	8:54	8:54	9:54	9:54	10:54	10:54	11:54	11:54					12:54	12:54					13:49	13:49		
DN	KGD	5:24	5:24	6:24	6:24			7:24	7:24					8:24	8:24					9:30	9:30		
	KNR	5:57	5:59	6:57	6:59			7:57	7:59	8:25	8:25			8:57	8:59	9:25	9:25			10:04	10:06	10:25	10:25
	KZH	6:36	6:38	7:36	7:38	8:20	8:20	8:36	8:38	9:02	9:04	9:20	9:20	9:36	9:38	10:02	10:04	10:20	10:20	10:43	10:45	11:02	11:04
	TRR	6:55	6:57	7:55	7:57	8:36	8:38	8:55	8:57	9:20	9:22	9:36	9:38	9:55	9:57	10:20	10:22	10:36	10:38	11:02	11:04	11:20	11:22
	TCR	7:20	7:22	8:20	8:22	9:02	9:04	9:20	9:22	9:46	9:48	10:02	10:04	10:20	10:22	10:46	10:48	11:02	11:04	11:27	11:29	11:46	11:48
	CIA	7:41	7:43	8:41	8:43	9:22	9:24	9:41	9:43	10:07	10:09	10:22	10:24	10:41	10:43	11:07	11:09	11:22	11:24	11:48	11:50	12:07	12:09
	ERS	7:51	7:53	8:51	8:53	9:32	9:34	9:51	9:53	10:16	10:18	10:32	10:34	10:51	10:53	11:16	11:18	11:32	11:34	11:57	11:59	12:16	12:18
	KOT	8:14	8:16	9:14	9:16	9:55	9:57	10:14	10:16	10:40	10:42	10:55	10:57	11:14	11:16	11:40	11:42	11:55	11:57	12:21	12:23	12:40	12:42
	CHN	8:30	8:32	9:30	9:32	10:11	10:13	10:30	10:32	10:55	10:57	11:11	11:13	11:30	11:32	11:55	11:57	12:11	12:13	12:37	12:39	12:55	12:57
	KLM	8:54	8:56	9:54	9:56	10:35	10:37	10:54	10:56	11:19	11:21	11:35	11:37	11:54	11:56	12:19	12:21	12:35	12:37	13:01	13:03	13:19	13:21
	TVM	9:18	9:18	10:18	10:18	11:00	11:00	11:18	11:18	11:44	11:44	12:00	12:00	12:18	12:18	12:44	12:44	13:00	13:00	13:25	13:25	13:44	13:44
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT		
UP	TVM	10:40	10:40	10:54	10:54	11:20	11:20	11:40	11:40	11:54	11:54	12:20	12:20	12:40	12:40	12:54	12:54	13:20	13:20	13:40	13:40		
	KLM	11:02	11:04	11:17	11:19	11:42	11:44	12:02	12:04	12:17	12:19	12:43	12:45	13:02	13:04	13:17	13:19	13:43	13:45	14:02	14:04		
	CHN	11:26	11:28	11:41	11:43	12:06	12:08	12:26	12:28	12:41	12:43	13:06	13:08	13:26	13:28	13:41	13:43	14:06	14:08	14:26	14:28		
	KOT	11:42	11:44	11:57	11:59	12:22	12:24	12:42	12:44	12:57	12:59	13:22	13:24	13:42	13:44	13:57	13:59	14:22	14:24	14:42	14:44		
	ERS	12:05	12:07	12:20	12:22	12:45	12:47	13:06	13:08	13:20	13:22	13:46	13:48	14:06	14:08	14:20	14:22	14:46	14:48	15:06	15:08		
	CIA	12:15	12:17	12:30	12:32	12:55	12:57	13:15	13:17	13:30	13:32	13:55	13:57	14:15	14:17	14:30	14:32	14:55	14:57	15:15	15:17		
	TCR	12:36	12:38	12:50	12:52	13:16	13:18	13:36	13:38	13:50	13:52	14:16	14:18	14:36	14:38	14:50	14:52	15:16	15:18	15:36	15:38		
	TRR	13:01	13:03	13:16	13:18	13:41	13:43	14:01	14:03	14:16	14:18	14:41	14:43	15:01	15:03	15:16	15:18	15:41	15:43	16:01	16:03		
	KZH	13:20	13:20	13:35	13:37	14:00	14:02	14:20	14:20	14:35	14:37	15:00	15:02	15:20	15:20	15:35	15:37	16:00	16:02	16:20	16:20		
	KNR			14:14	14:16	14:39	14:39			15:14	15:16	15:39	15:39			16:14	16:16	16:39	16:39				
	KGD			14:49	14:49					15:49	15:49					16:49	16:49						
DN	KGD			10:30	10:30					11:30	11:30					12:30	12:30						
	KNR			11:04	11:06	11:25	11:25			12:04	12:06	12:25	12:25			13:04	13:06	13:25	13:25				
	KZH	11:20	11:20	11:43	11:45	12:02	12:04	12:20	12:20	12:43	12:45	13:02	13:04	13:20	13:20	13:43	13:45	14:02	14:04	14:20	14:20		
	TRR	11:36	11:38	12:02	12:04	12:20	12:22	12:36	12:38	13:02	13:04	13:21	13:23	13:36	13:38	14:02	14:04	14:21	14:23	14:36	14:38		
	TCR	12:02	12:04	12:27	12:29	12:46	12:48	13:02	13:04	13:27	13:29	13:46	13:48	14:02	14:04	14:27	14:29	14:46	14:48	15:02	15:04		
	CIA	12:22	12:24	12:48	12:50	13:07	13:09	13:23	13:25	13:48	13:50	14:07	14:09	14:23	14:25	14:48	14:50	15:07	15:09	15:23	15:25		
	ERS	12:32	12:34	12:57	12:59	13:16	13:18	13:32	13:34	13:57	13:59	14:16	14:18	14:32	14:34	14:57	14:59	15:16	15:18	15:32	15:34		
	KOT	12:55	12:57	13:21	13:23	13:40	13:42	13:56	13:58	14:21	14:23	14:40	14:42	14:56	14:58	15:21	15:23	15:40	15:42	15:56	15:58		
	CHN	13:11	13:13	13:37	13:39	13:55	13:57	14:11	14:13	14:37	14:39	14:56	14:58	15:11	15:13	15:37	15:39	15:56	15:58	16:11	16:13		
	KLM	13:35	13:37	14:01	14:03	14:19	14:21	14:35	14:37	15:01	15:03	15:19	15:21	15:35	15:37	16:01	16:03	16:19	16:21	16:35	16:37		
	TVM	14:00	14:00	14:25	14:25	14:44	14:44	15:00	15:00	15:25	15:25	15:44	15:44	16:00	16:00	16:25	16:25	16:44	16:44	17:00	17:00		
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	
UP	TVM	14:01	14:01	14:20	14:20	14:40	14:40	15:01	15:01	15:20	15:20	15:40	15:40	16:01	16:01	16:20	16:20	16:40	16:40	17:01	17:01	17:20	
	KLM	14:24	14:26	14:43	14:45	15:02	15:04	15:24	15:26	15:43	15:45	16:03	16:05	16:24	16:26	16:43	16:45	17:03	17:05	17:24	17:26	17:43	
	CHN	14:48	14:50	15:06	15:08	15:26	15:28	15:48	15:50	16:06	16:08	16:27	16:29	16:48	16:50	17:07	17:09	17:27	17:29	17:48	17:50	18:07	
	KOT	15:04	15:06	15:22	15:24	15:42	15:44	16:04	16:06	16:22	16:24	16:42	16:44	17:04	17:06	17:23	17:25	17:42	17:44	18:04	18:06	18:23	
	ERS	15:27	15:29	15:46	15:48	16:06	16:08	16:27	16:29	16:46	16:48	17:06	17:08	17:27	17:29	17:46	17:48	18:06	18:08	18:27	18:29	18:46	
	CIA	15:37	15:39	15:55	15:57	16:15	16:17	16:37	16:39	16:55	16:57	17:15	17:17	17:37	17:39	17:55	17:57	18:15	18:17	18:37	18:39	18:55	
	TCR	15:57	15:59	16:16	16:18	16:36	16:38	16:57	16:59	17:16	17:18	17:36	17:38	17:57	17:59	18:16	18:18	18:36	18:38	18:57	18:59	19:16	
	TRR	16:23	16:25	16:41	16:43	17:01	17:03	17:23	17:25	17:41	17:43	18:02	18:04	18:23	18:25	18:42	18:44	19:02	19:04	19:23	19:25	19:42	
	KZH	16:42	16:44	17:00	17:02	17:20	17:20	17:42	17:44	18:00	18:02	18:20	18:20	18:42	18:44	19:00	19:02	19:20	19:20	19:42	19:44	20:00	
	KNR	17:21	17:23	17:39	17:39			18:21	18:23	18:39	18:39			19:21	19:23	19:39	19:39			20:21	20:23	20:39	
	KGD	17:56	17:56					18:56	18:56					19:56	19:56					20:56	20:56		
DN	KGD	13:30	13:30					14:25	14:25					15:25	15:25					16:25	16:25		
	KNR	14:04	14:06	14:25	14:25			14:59	15:01	15:25	15:25			15:59	16:01	16:25	16:25			16:59	17:01	17:25	
	KZH	14:43	14:45	15:02	15:04	15:20	15:20	15:38	15:40	16:02	16:04	16:20	16:20	16:38	16:40	17:02	17:04	17:20	17:20	17:38	17:40	18:02	
	TRR	15:02	15:04	15:21	15:23	15:37	15:39	15:57	15:59	16:21	16:23	16:37	16:39	16:57	16:59	17:21	17:23	17:37	17:39	17:57	17:59	18:21	
	TCR	15:27	15:29	15:46	15:48	16:02	16:04	16:22	16:24	16:46	16:48	17:02	17:04	17:22	17:24	17:46	17:48	18:02	18:04	18:22	18:24	18:46	
	CIA	15:48	15:50	16:07	16:09	16:23	16:25	16:43	16:45	17:07	17:09	17:23	17:25	17:43	17:45	18:07	18:09	18:23	18:25	18:43	18:45	19:07	
	ERS	15:57	15:59	16:16	16:18	16:32	16:34	16:52	16:54	17:16	17:18	17:32	17:34	17:52	17:54	18:17	18:19	18:32	18:34	18:52	18:54	19:17	
	KOT	16:21	16:23	16:40	16:42	16:56	16:58	17:16	17:18	17:40	17:42	17:56	17:58	18:16	18:18	18:40	18:42	18:56	18:58	19:16	19:18	19:40	
	CHN	16:37	16:39	16:56	16:58	17:12	17:14	17:31	17:33	17:56	17:58	18:12	18:14	18:31	18:33	18:56	18:58	19:12	19:14	19:31	19:33	19:56	
	KLM	17:01	17:03	17:19	17:21	17:36	17:38	17:55	17:57	18:19	18:21	18:36	18:38	18:55	18:57	19:20	19:22	19:36	19:38	19:55	19:57	20:20	
	TVM	17:25	17:25	17:44	17:44	18:00	18:00	18:20	18:20	18:44	18:44	19:00	19:00	19:20	19:20	19:44	19:44	20:00	20:00	20:20	20:20	20:44	
		IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT		
UP	TVM	17:40	17:40	18:01	18:01	18:20	18:20	18:40	18:40	18:56	18:56	19:20	19:20	19:40	19:40	19:56	19:56	20:56	20:56	21:56	21:56		
	KLM	18:03	18:05	18:24	18:26	18:43	18:45	19:03	19:05	19:19	19:21	19:43	19:45	20:03	20:05	20:19	20:21	21:19	21:21	22:19	22:21		
	CHN	18:27	18:29	18:48	18:50	19:07	19:09	19:27	19:29	19:43	19:45	20:07	20:09	20:27	20:29	20:43	20:45	21:43	21:45	22:43	22:45		
	KOT	18:42	18:44	19:04	19:06	19:23	19:25	19:43	19:45	19:58	20:00	20:23	20:25	20:43	20:45	20:58	21:00	21:58	22:00	22:58	23:00		
	ERS	19:06	19:08	19:27	19:29	19:46	19:48	20:06	20:08	20:22	20:24	20:46	20:48	21:06	21:08	21:22	21:24	22:22	22:24	23:22	23:22		
	CIA	19:15	19:17	19:37	19:39	19:55	19:57	20:16	20:18	20:31	20:33	20:55	20:57	21:16	21:18	21:31	21:33	22:31	22:33				
	TCR	19:36	19:38	19:57	19:59	20:16	20:18	20:36	20:38	20:52	20:54	21:16	21:18	21:36	21:38	21:52	21:54	22:52	22:52				
	TRR	20:02	20:04	20:23	20:25	20:42	20:44	21:02	21:04	21:18	21:20	21:42	21:44	22:02	22:04	22:18	22:20						
	KZH	20:20	20:20	20:42	20:44	21:00	21:02	21:20	21:20	21:36	21:38	22:00	22:02	22:20	22:20	22:36	22:38						
	KNR			21:21	21:23	21:39	21:39			22:15	22:17	22:39	22:39			23:15	23:15						
	KGD			21:56	21:56					22:51	22:51												
DN	KGD			17:25	17:25					18:32	18:32			19:32	19:32	20:32	20:32	21:32	21:32				
	KNR			17:59	18:01	18:25	18:25			19:06	19:08	19:25	19:25	20:06	20:08	21:06	21:08	22:06	22:08				
	KZH	18:20	18:20	18:38	18:40	19:02	19:04	19:20	19:20	19:45	19:47	20:02	20:04	20:45	20:47	21:45	21:47	22:45	22:47				
	TRR	18:37	18:39	18:57	18:59	19:21	19:23	19:37	19:39	20:03	20:05	20:21	20:23	21:03	21:05	22:03	22:05	23:03	23:05				
	TCR	19:02	19:04	19:22	19:24	19:46	19:48	20:02	20:04	20:29	20:31	20:46	20:48	21:29	21:31	22:29	22:31	23:29	23:29				
	CIA	19:23	19:25	19:43	19:45	20:07	20:09	20:23	20:25	20:50	20:52	21:07	21:09	21:50	21:52	22:50	22:52						
	ERS	19:32	19:34	19:52	19:54	20:17	20:19	20:33	20:35	20:59	21:01	21:17	21:19	21:59	22:01	22:59	22:59						
	KOT	19:56	19:58	20:16	20:18	20:40	20:42	20:56	20:58	21:23	21:25	21:40	21:42	22:23	22:25								
	CHN	20:12	20:14	20:31	20:33	20:56	20:58	21:12	21:14	21:38	21:40	21:56	21:58	22:38	22:40								
	KLM	20:36	20:38	20:55	20:57	21:20	21:22	21:36	21:38	22:02	22:04	22:20	22:22	23:02	23:04								
	TVM	21:00	21:00	21:20	21:20	21:44	21:44	22:00	22:40	22:27	22:27	22:44	22:44	23:27	23:27								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KGD

DETAILED PROJECT REPORT

SEMI HIGH SPEED RAIL CORRIDOR
THIRUVANANTHAPURAM TO KASARAGOD

VOLUME II - MAIN REPORT
(PART C)

CHAPTER 14
ENVIRONMENTAL & SOCIAL IMPACT ASSESSSMENT

14 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

DISCLOSURE OF CONSULTANT ENGAGED IN EIA STUDY

M/s. Centre for Environment and Development

The Centre for Environment and Development (CED) is an autonomous research and development, training and consultancy organisation focussing in areas related to Environment and Development and is recognised as a Scientific and Industrial Research Organisation (SIRO) by the Department of Scientific and Industrial Research of the Ministry of Science and Technology, Government of India. CED is also the Centre of Excellence on Solid Waste and Wastewater Management of Ministry of Housing and Urban Development, Government of India, Empanelled Agency for the Preparation of City Development Plan (CDP) for the ULBs and also Preparation of DPR for Water Supply, Sanitation and Drainage and the Training Institute of the MoUD for AMRUT and Smart Cities Mission. It is one of the National Key Resource Centre for Drinking Water and Sanitation of the Ministry of Drinking Water and Sanitation, Government of India and the Regional Resource Agency of Ministry of Environment and Forests and Climate Change, Government of India. CED is also an empanelled agency of Indian Council for Forestry Research and Education (ICFRE), Ministry of Environment Forests and Climate Change, Government of India for projects related to Environment Management. CED is also the Accredited Agency of Government of Kerala for Solid Waste Management and Participatory Resource Mapping.

CED is an ISO 9001 – 2015 Certified Institution. CED has completed nearly 120 projects sponsored by various State, national and International Agencies during the last 27 years. CED has its Head Quarters at Thiruvananthapuram and Eastern Regional Campus at Bhubaneswar, Regional Centre at Hyderabad and projects and programs in Kerala, Odisha, Andhra Pradesh, Telangana, Jharkhand, West Bengal, Gujarat, Maharashtra, Madhya Pradesh, Jammu Kashmir, Uttarakhand, Rajasthan, Himachal Pradesh and Karnataka.

The EIA has been carried out by the experts in the Head office, Thiruvananthapuram. The overall objective of the assignment is to carry out a Rapid Environment Impact Assessment (EIA) for the proposed Silver line Project in the State of Kerala, running between Thiruvananthapuram to Kasaragod (Total Length of corridor: 529.450 km). The details of Team Leader for the EIA study and other experts involved are as given below:

i. Dr. Vinod T R, Program Director, CED - Team Leader; Forestry & Wildlife Specialist
ii. Dr. Radhakrishnan P V, Program Director, CED - Environmental & Legal Expert
iii. Dr. T. Sabu, Program Director, CED - Biodiversity and Taxonomy Expert

iv. Dr. Thrivikramanji K P, Emeritus Professor, CED - Geologist, GIS and RS Specialist
v. Er. Jayaram B, Former Chief Engineer, Irrigation Department, GoK - Hydrology Specialist
vi. Dr. Manilal, Former Chief Scientist, NIIST (CSIR), GoI - Senior Advisor (Environment)
vii. Dr. Krishnakumar, Consultant, CED - Social Expert
viii. Sri. V T Joseph, Former Asst Development Commissioner, GoK - Social Expert
ix. Er. Reghukumar P, Senior Design Engineer, CED - Design Specialist
x. Dr. Chrips N R, Scientist, CED - Botany, GIS and RS Specialist
xi. Mr. Baiju P, Program Officer, CED - Social & Logistic Specialist
xii. Mr. Arun C Rajan, Research Fellow, CED - Field Biologist
xiii. Mr. Don Mathew, Research Fellow, CED - Environment Specialist
xiv. Mr. Jitin J Paul, Research Fellow, CED - Environment Specialist
xv. Mr. Prasood S P, Research Fellow, CED - Geology, GIS and RS Specialist

14.1 INTRODUCTION

Kerala is considered the “Gateway of Southern India”. This is one of the states of India attracting large numbers of tourist and having the highest literacy rate in the country. Kerala state is located between Latitude 8° 18' & 12° 48'N and Longitudes 74° 52' & 72° 22'E. This is the land of eternal beauty, which encompasses 1.18% land of the country.

Kerala is in the southwestern part of India. With Arabian Sea coastline on the west, it is bordered by Karnataka on the North and Tamil Nadu in the South & East. Kerala is spread over an area of 38,863 sq.km. It has a total coastline of 580 km. Its width varies from 120 km at its maximum and just 30 km at its minimum.

The coastal state of Kerala lying on the south-western tip of India has been commonly been called the tropical paradise of India. The Arabian Sea is on one side and the Western Ghats is on another cover of the Kerala state. The area is marked as coastal zone of Arabian Sea. This coastal state possesses hot and humid climate during April - May and pleasant cold during December-January. Kerala has total 14 districts; eleven districts shall fall on the Silver Line Rail Corridor alignment/route. As per 2011 Census, the state has a population 33.40 million people. Out of which 28.67 million (85.83%) are in those districts through which the semi high speed rail corridor will pass (11 districts upto Kasaragod). Sex ratio is 1084 females per 1000 males. Although Kerala accounts for only 1.18% of the total area of India, it contains about 3% of the country’s population. The population density of the state is about 860 persons/sq.km, about three times higher than the national average. Kerala is one of the densest states in the country and it has recorded a decadal population growth of +9.42% during 1991 to 2001 and further 4.91% during 2001 to 2011. Overall literacy rate is about 94%.

14.1.1 Need of the Project

Kerala State, which has one of the highest densities of population in India, has eleven National Highways which run for about 1781.5 km. There are 72 state highways in Kerala. Of them, MC Road (Main-Central Road), proposed Hill Highway (Kerala) and Main Eastern Highway are the longest. The road transport infrastructure of the state consists of over 2.29 lakh kms of road and road density in Kerala is 590 km per 100 square km (which includes classified & non-classified roads). The road traffic has been growing at a rate of 10 to 12%, whereas Road length growth has been negligible. This has resulted in great increase in the road congestion. Four international airports at Thiruvananthapuram, Kochi, Kozhikode and Kannur, link the state with the rest of the nation and so the world. The total rail network in Kerala is 1045 km in length, with 181 stations and serving 9 routes, connects all major towns and cities of Kerala except in highland districts of Idukki and Wayanad. The existing railway and road networks in the state are not amenable to faster travel. Average speed on road and by trains in the State is among the lowest of all regions of the country. Hence, the necessity for developing Silver Line rail corridors has been felt, which will cater the needs of rapidly growing and expanding economy and thereby curb the high road-based greenhouse gas emissions.

A detailed proposal on proposed Silver Line project from Thiruvananthapuram to Kasaragod was presented before Railway Board, Government of India on 10th December 2019. While according in-principle approval, Railway Board has expressed concern about the land acquisition issues in Kerala. It was assured that all efforts will be made to acquire the land and proper compensation will be given to the affected parties.

The Silver Line expected to be completed by 2025, will reduce journey time from Thiruvananthapuram to Kasaragod from about 12 hours to just 4 hours. This line will reduce congestion and pollution on the roads, improve safety and comforts. The positive impacts of the project are safety; High Capacity and Frequency; High Energy Efficiency and Low Emission of Greenhouse Gas (Reduce impact of Climate Change); Travel time reduction; Employment generation; and Strong Infrastructure to counter Natural Disaster.

14.1.2 Objectives and Scope of EIA Study

The prime objective of the environmental impact assessment study is to identify the likely adverse and positive environmental and social impacts/ issues during various phases (pre construction, construction and operation) of the project implementation, suggest avoidance, mitigation and enhancement measures and develop cost effective mitigation and monitoring measures along with an institutional mechanism to enhance the environmental sustainability of the project.

The specific objectives of the ESIA study are;

- To identify, assess, and evaluate potential environmental and social impacts to be considered in the Silver Line Project Corridor.
- To recommend specific mitigation, management, and monitoring measures to avoid, offset or minimize the impacts.
- To formulate an EMP and EMoP integrating the technically and economically feasible measures to minimize and avoid the identified adverse impacts.
- To recommend suitable institutional mechanisms to monitor and supervise effective implementation of EMP and EMoP.

The scope of the study is to meet the requirements of statutory authorities such as State Pollution Control Boards, Ministry of Environment, Forests and Climate Change and funding agencies such as KfW, Asian Development Bank, World Bank, JICA, AIIB, etc.

14.2 PROJECT DESCRIPTION

The proposed Silver Line rail alignment starts from the east side of Kochuveli railway station near Thiruvananthapuram and ends at Kasaragod. This rail line will pass through eleven districts, and will stop at 11 main stations namely Thiruvananthapuram, Kollam, Chengannur, Kottayam, Ernakulam, Cochin Airport, Thrissur, Tirur, Kozhikode, Kannur and Kasaragod. The total length of Silver Line rail alignment is 529.450 km consisting of tunnels, viaducts and embankments. The salient features of Silver Line rail project are given in Table 14-1.

Table 14-1: Salient features of Silver Line Rail Project

Sl. No.	Description	Details
1	Route Length	529.450 km
2	Gauge	1435 mm (Standard Gauge)
3	Maximum Operational Speed	200 km/h
4	Stations	Thiruvananthapuram at Kochuveli, Kollam, Chengannur, Kottayam, Ernakulam, Kochi Airport, Thrissur, Tirur, Kozhikode, Kannur and Kasaragod
5	Type of Structures	Tunnels – 11.528 km (2.17%), Bridges– 12.991 km (2.44%), Viaducts – 88.412 km (16.61%), Embankments – 292.728 km (55.00%), Cuttings – 101.737 km (19.12%), Cut & Cover- 24.789 km (4.66%)
6	Track Structure	Mostly Ballasted and ballast-less in viaduct & tunnels

Sl. No.	Description	Details
7	Maintenance Depots	Workshop at Kollam and Inspection Depot at Kasaragod
8	Train type	EMU type
9	Car body Width	3400mm (max)
10	Seating	2+2 (Business), 3+2 (Standard)
11	Passenger capacity per Train	675 (9 car set)
12	Traction	2x25kV Auto Transformer Type Feeding System Overhead Contact System – simple catenary type
13	Power Supply	Kerala State Electricity Board supply supplemented by renewable energy supplies
14	Signalling & Train Control System	ETCS level 2 system
15	Communication	LTE with BTN
16	Daily Ridership	79934 in 2025 – 26 increasing to 158946 in 2052 – 53
17	Train Set	9 cars extendable to 12/15
18	Train operation	37 services in 2025 – 26 with peak headway of 20 minutes, increasing to 65 in 2052 – 53 with peak headway of 10 minutes
19	Cars requirement	261 in 2025 increasing to 492 in 2052
20	Fare Collection	Automatic Fare collection system with Centralized Computer and other supporting systems
21	Completion time	5 years
22	Capital cost (Rs) (March 2020 price)	49919 Crores
23	Cost with IDC (Rs)	63941 Crores
24	Financing	Debt Rs.33700cr (52.7%), Equity-MoR-Rs.3125cr (4.89%), GoK-Rs.3253cr (5.09%) and other equities-4252cr (6.65%), GoK (land, EIA and R&R)-13362cr (20.90%), Subordinated debt-GoI-Rs.3189cr (4.99%), GoK-Rs.2896cr (4.53%) and balance in IDC-Rs164cr (0.26%)

14.2.1 Route and Stations

Silver Line rail corridor between Thiruvananthapuram and Kasaragod will start from east side of existing Kochuveli Railway Station, Thiruvananthapuram. Total 11 main stations are planned along the entire route from Thiruvananthapuram to Kasaragod. Latitudes, longitudes and chainage of all stations are presented in Table 14-2. Horizontal alignment has been designed for the maximum operating speed of 200 kmph for Passenger train and maximum speed of 120 kmph for fast freight. The planned route lies between Latitude 8°30'44.94"N-Longitude 76°53'50.63"E and Latitude 12°29'27.51"N-Longitude 74°59'13.30"E.

Table 14-2: Details of Stations of Silver Line Rail Project

Sl. No.	Station Name	Latitude	Longitude	Chainage (km)
1	Thiruvananthapuram	8°30'44.94"N	76°53'50.63"E	0
2	Kollam	8°53'44.51"N	76°39'25.56"E	55.338
3	Chengannur	9°18'28.66"N	76°38'26.37"E	102.900
4	Kottayam	9°34'33.43"N	76°32'18.74"E	136.108
5	Ernakulam	10° 0'48.99"N	76°22'36.56"E	195.329
6	Kochi Airport	10° 9'21.98"N	76°22'51.02"E	212.318
7	Thrissur	10°30'31.32"N	76°12'19.67"E	259.117
8	Tirur	10°56'46.40"N	75°54'8.66"E	320.562
9	Kozhikode	11°14'49.70"N	75°46'46.89"E	357.868
10	Kannur	11°52'19.04"N	75°22'8.96"E	446.095
11	Kasaragod	12°29'27.51"N	74°59'13.30"E	529.450

14.2.2 Maintenance Depots

There are two maintenance depots proposed, one at Kollam and second at Kasaragod. Latitudes, longitudes and chainage of depots are presented in Table 14-3.

Table 14-3: Maintenance Depot Locations

Sl. No.	Depot Name	Latitude	Longitude	Chainage (km)
1	Kollam Depot	8°53'3.23"N	76°38'53.47"E	55.338
2	Kasaragod Depot	12°30'45.59"N	74°58'21.03"E	530.953

14.2.3 Land Requirement

Land required for the alignment (Viaduct, embankment, Cutting etc.) and for stations together works out to 1383 Ha. This includes 185 Ha of Rly land between Tirur and Kasaragod and between Kochuveli and Murukkumpuzha stations of S. Railway and the balance 1198 Ha of private land. In addition, temporary land will be required for casting depots and for movements of material and machinery vehicles during construction period.

14.2.4 Water Requirement

In the Construction Phase approximately 30 MLD of water will be required and in Operational Phase approximately 5 MLD water demand is envisaged. The demand will be distributed along the alignment, at the stations, construction camps, maintenance depots, rolling stock, *etc*. and will be sourced from local municipal supply as well as tanker supplied water (as approved by local authorities).

14.2.5 Project Implementation Schedule

Based on the information disclosure of K-Rail, The project is expected to be commissioned over a period of five years from 2020-21 to 2024-25. All the clearances required for the commencement of construction activities shall be secured before commencement of the construction activities.

14.2.6 Tunnels, Viaducts, Embankments, Cuttings and Cut & Cover

The breakup of the alignment at grade (cutting, banking), elevated, Bridges and underground is presented in Table 14-4.

Table 14-4: Details of Structures

Sl. No.	Type of Structure	Approx. Length (km)	(%) of Route Length
1	Tunnels	11.528	2.17
2	Bridges	12.991	2.44
3	Viaducts	88.412	16.61
4	Embankments	292.728	55.00
5	Cuttings	101.737	19.12
6	Cut & Cover	24.789	4.66
Total		532.185	100
Total Route Length from Thiruvananthapuram Station to Kasaragod Station		**529.450 km**	

14.3 APPLICABLE POLICY, LEGAL & ADMINISTRATIVE FRAMEWORK

The Government of India has issued Environmental Impact Assessment Notification in 1994 as a part of Environmental (Protection) Act, 1986 and amendments in September 2006. Railway projects do not fall under any category requiring an environmental clearance from MoEFCC. Only No Objection Certificate (NOC) is required from SPCB under the Air and Water Acts for operating various equipment during construction works.

The Environmental and Other Applicable Cross-Sectoral Acts, Rules and Norms which are generally relevant to Semi High Speed Rail Projects are listed below:

- The Environment Protection Act,1986
- Environmental Impact Assessment Notification-14th Sep-2006 and its amendment
- Air (Prevention and Control of Pollution) Act, 1981
- Water (Prevention and Control of Pollution) Act,1974
- Noise Pollution (Regulation and Control Act), 2000
- Forests (Conservation) Act, 1980 and its amendments
- The Forest (Conservation) Rules, 1981
- The State Forest Acts
- Wild Life (Protection) Act, 1972 and its amendments
- National Green Tribunal Act, 2010
- National Green Tribunal (Prevention and Protection) Rules, 2011
- The Biological Diversity Act 2002 and its Rules, 2007
- Coastal Regulation Zones Rules 2011 and its amendment 18th January 2019
- Wetlands (Conservation and Management) Rules, 2010
- Construction & Demolition (C&D) Waste Management Rules, 2016
- Solid Waste Management Rules, 2016
- Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2016
- Municipal Solid Wastes (Management and Handling) Rules, 2000.
- MoEFCC circular (1998) on linear Plantation on roadside, canals and railway lines modifying the applicability of provisions of forest (Conversation) Act, to linear Plantation
- Public Liability and Insurance Act, 1991 and its Amendment, 1992
- The Explosives Act 1884
- Central Motor Vehicle Act 1988 and Central Motor Vehicle Rules,1989
- The Railway (Amendment) Act, 2008
- The Petroleum (Amendment) Rules, 2011
- Land Acquisition Act, 1984 and its Amendment
- National Rehabilitation and Resettlement Policy, 2007
- The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013, (RTFCTLARRA 2013)
- The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Kerala) Rules.

14.3.1 Category of the Project

The Silver Line rail project does not attract requirements of prior Environmental Clearance (EC) from MoEFCC as per EIA Notification, 2006 in India, as the Railway sector is not included in the Schedule of the notification. Railway projects come under Category A as per JICA's Guidelines for Environmental and Social Considerations, April 2010, therefore the Silver Line Project will come in Category A.

14.3.2 Environmental Clearances and Permissions

The clearances and permissions required under existing environmental legislation to implement the Project are summarized below in Table 14-5.

Table 14-5: Clearances and Permissions Required for Silver Line Project

Sl. No.	Description of Clearances	Acts/Rules	Authority to Accord Clearance	Applicability to the Project
1	Environmental Clearance (EC)	Environment (Protection) Rules, 1986; EIA Notification 2006	MoEFCC	EC is exempted for the project.
	Pre-Construction Stage			
2	Diversion of forest Land for Non-forest use	Forest Conservation Act, 1980 Forest Conservation Rules, 2003	MoEFCC	Not Applicable
3	Permission for Mangrove Felling	Forest Conservation Act, 1980		Applicable
4	CRZ Clearance for Undertaking construction activities in coastal zone	CRZ Notification 2011 and its amendment 2019	MoEFCC after recommendation from KCZMA	Applicable
	Project Implementation Stage			
5	No Objection Certificate (NOC)	Water (Prevention and Control of Pollution) Act,1974, Air (Prevention and Control of Pollution) Act,1981	Kerala State Pollution Control Board	Applicable
6	NOC for undertaking construction activities within 200 m of the notified heritage site	The Ancient Monuments and Archaeological Sites and Remains Act, 1958	Expert Advisory Committee of ASI	Applicable
7	Permission for Withdrawal of Surface Water from Rivers, Nallah, Water harvesting structure/ Reservoirs/Ponds/Irrigation canals	Relevant Government orders & circulars	Irrigation Department, GoK	Applicable (If the contractor is extracting Surface water)

Sl. No.	Description of Clearances	Acts/Rules	Authority to Accord Clearance	Applicability to the Project
8	Permission for withdrawal of ground water and NOC for construction of tube well/bore well	Ground Water Regulation and Control of Development and Management Act, 2005	Central Ground Water Board	Applicable (if the contractor abstract ground water)
9	Permission for Sand Mining from riverbed	Mines and Minerals (Development and Regulation) Act,1957 as amended in 1972	Dept. of Mines & Geology, GoK	Applicable
10	Opening of New Quarry	Mines and Minerals (Development and Regulation) Act,1957 as amended in 1972	Dept. of Mines & Geology, GoK	Applicable
11	Hot mix plant, Crushers, Cement Batching Plant	Air (Prevention and Control of Pollution) Act,1981	Kerala State Pollution Control Board	Applicable
12	Storage of Hazardous Chemicals	Hazardous and Other Waste (Management and Handling) Rules, 2016	Kerala State Pollution Control Board	Applicable
13	Disposal of Hazardous Waste	Hazardous and Other Waste (Management and Handling) Rules, 2016	Kerala State Pollution Control Board	Applicable
14	Construction Waste	Construction & Demolition Waste Management Rules, 2016	Kerala State Pollution Control Board	Applicable
15	Wastewater discharge from labour camps	Water (Prevention and Control of Pollution) Act, 1974	Kerala State Pollution Control Board	Applicable
16	Pollution Under Control Certificate	Central Motor Vehicles Act,1988	Kerala Motor Vehicles Department	Applicable
17	Power Supply	Kerala Electricity Regulatory Commission (Electricity Supply Code and Other Conditions of Supply) Regulations	Kerala State Electricity Board	Applicable
18	Employing Labour	Executing Agency of Building and Other Construction Workers (Regulation of Employment & Conditions of Service) Act, 1996	Department of Labour, GoK	Applicable

Sl. No.	Description of Clearances	Acts/Rules	Authority to Accord Clearance	Applicability to the Project
19	Registration of Workers	Labour Welfare Acts	Department of Labour, GoK	Applicable
20	Approval of Building plan & building permit	KMBR & KPBR	Local Self Governments, Kerala	Applicable
21	License to store HSD and Explosives at Construction camp by the contractors from Chief Controller of Explosives under Petroleum Acts and Rules	The Petroleum Act, 1934 and The Petroleum Rules,1976 and its amendments.	Regional office of Chief Controller of Explosives, Chennai	Applicable

14.4 BASELINE ENVIRONMENTAL QUALITY & SOCIO-ECONOMIC STATUS

Generation of environmental and social baseline of a project area is an important phase of any Environmental and Social Assessment process. Baseline data provide vital information on the existing environmental quality and socio-economic status in which development program is planned.

In this study, the environmental and social characteristics of the project area were established through extensive literature search, secondary data available with various Govt. Departments, Research/Academic Institutes and published documents/ research papers.

The proposed Silver Line rail project is expected to bring changes that are more positive to the residents along the corridor location and surrounding towns in terms of improving level of modern transportation within the Kerala region with other parts of the country, ease of conducting business, access to markets, medical facilities, schools and other social facilities.

Silver Line rail offers tangible advantages over other transport modes such as air, conventional rail and private vehicles for medium to long distance journeys. Considering the evaluation of complete life cycle of transportation systems in terms of sustainability, Silver Line rail is one of the most efficient mode of transport. At the same time, it combines many of the attributes that we most desire while travelling such as speed, reliability, comfort and safety.

14.4.1 Baseline Environmental Quality Status

Physical environment includes air, meteorology, noise, water, soil, land, biological environment includes aquatic and terrestrial flora & fauna while social environment includes demographic details, civic infrastructure, public services, surrounding monuments, commercial facilities, employment levels, sources and levels of income, economic base of the area, land values, land ownership, etc.

Knowledge of the quality of baseline bio-physical surroundings of the impact zone is useful for impact assessment (assessing and predicting the environmental consequences of the significant actions).

14.4.1.1 Topography

Kerala, the southernmost State of India lies in between 8°18' and 12°48' N latitude and 74°52' and 72°22' E longitude. Kerala has an undulating topography, from the steep hills of the Western Ghats (with valleys and hills) in the east to the Malabar coast (with plain lands) to the west. The total geographic area of the State is 38,86,300 ha. Kerala borders with Tamil Nadu and Karnataka to its east and north-east, and the Lakshadweep Sea to its west, respectively.

14.4.1.2 Physiography

There are mainly three broad physiographic divisions in the State, viz., lowlands, middle lands and highlands.

- The low land (covers 10.24%) is adjacent to the coast and extends up to an altitude of 7.5 m MSL, with extensive coconut groves, paddy fields, and backwaters.
- The midland region (covers 41.76%) having an undulating topography which extends from 7.5 m to 75 m above MSL, is made up of fertile reddish hills and valleys that grow most of Kerala's agricultural crops.
- The high land (covers 48% of the State) is on the eastern part consisting of peaks, extensive ridges and ravines of the Western Ghats which extends from 75 m MSL and above.

A physiographic classification, identified mainly in terms of broad geomorphic surfaces and altitudinal characteristics, is also used in the parlance of geographers (CESS, 1984). It has five physiographic zones, namely, high ranges with elevation above 600 m, foothill zone between 300 to 600 m, upland regions between 100 - 300 m, midland between 20 - 100 m and coastal areas and low land below an altitude of 20 m.

14.4.1.3 Geology

The geology of Kerala is a part of the south Indian Precambrian terrain, which is composed of granulites, gneisses, granites and greenstones. The granulites and associated gneisses belong to the Precambrian in Kerala state. The younger Meso-Cenozoic dykes and pegmatites are found to intrude late Precambrian rocks. The tertiary sedimentary formations of 14 the land belong to Neogene period only (Soman, 2002). The Charnockites and charnockitic gneisses are the oldest rock complex units of Kerala state. Charnockitic gneisses, gneisses and the pyroxene-bearing granulites occupy the major parts of the Western Ghats and the midland regions located within

Kerala state. The granulitic gneisses are very well spatially connected with lineaments and faults in Kerala state (Soman, 2002). Khondalites are yet another major rock formation of south Kerala and are associated with garnet-biotite gneiss and garnetiferous quartzofeldspathic gneiss. The presence of intrusives especially, the dykes, have hydrogeological role to find good zones of water bearing fractures. Intrusive formation dykes of Lower-Middle Proterozoic age, pegmatites of Middle Proterozoic age, host of younger granites (Late Precambrian-early Palaeozoic age) and later dolerite dykes, contemporaneous with Cretaceous-Paleocene Deccan Basalt magmatism, are the common elements seen in granulitic terrain of this state. The western parts of the State consist of sedimentary formations of Neogene period and quaternary period having four distinct beds viz. Alleppey, Vaikom, Quilon and Warkali. In midland regions, the Tertiary and crystalline formations are found as lateritized units which act as good aquifer. Along the coastal regions, alluvial deposits of Recent origin are found. The general stratigraphic sequence is given in Table 14-6.

Table 14-6: General Stratigraphic Sequence of Kerala State

Period	Formation	Lithology
Quaternary	Vembanad formation	Sand, Clay, Molluscan shell beds, riverine alluvium and flood plain deposits, laterite capping the crystalline and Tertiary sediments
Tertiary	Warkalli formation	Sandstone, clay with lignite seams
	Quilon formation	Limestone, marls, clay/ calcareous clays with marine fossils
	Vaikom formation	Sandstone with pebbles and gravels beds, clays and lignite and carbonaceous clay.
Mesozoic to Archean	Intrusive	Veins of quartz, pegmatites, granite, granophyres, dolerite and gabbro.
	Crystalline	Garnet sillimanite gneiss, Hornblende biotite gneiss, garnet biotite gneiss, quarto –feldspathic gneiss, charnockites, charnockite gneiss, etc.

Source: EIA Study Team

14.4.1.4 Climate and Meteorology

The climate of Kerala is tropical monsoon with seasonally excessive rainfall and hot summer. The Western Ghats plays a major role in the climatic conditions that prevail all along the state. The period of March to the end of May is the hot season which is the summer. This is followed by South West Monsoon season that continues till the beginning of October. From October to December is the North East Monsoon season and two months, January and February, are the winter. The climate is pleasant from September to February. Classification of Seasons are presented in below Table 14-7.

Table 14-7: Classification of Seasons of Kerala

Sl. No.	Seasons	Duration	Intensity of Rainfall
1	Wet Season a. Kalavarsha (South West Monsoon) b. Thulavarsha (North East Monsoon)	June to September October to December	Very Heavy Rainfall Heavy Rainfall
2	Dry Season (Winter)	January to February	Occasional Rainfall
3	Hot Season (Summer)	March to May	Occasional Rainfall

Source: EIA Study Team

14.4.1.4.1 Temperature

December, January and February represent winter months with daily mean minimum temperature around 18°C and daily mean maximum temperature around 28°C. March till May is the summer season in Kerala with daily mean maximum temperature at 36°C and daily mean minimum temperature at 32°C. The rainy season in Kerala is the Southwest monsoon (June to September). During monsoon daily mean maximum and minimum temperature recorded around 30°C and 19°C respectively.

14.4.1.4.2 Relative Humidity

As the State stretches from north to south with the Arabian Sea in its west, relative humidity is in general high over the State. In the period January to March afternoon humidity reduce to 60-63%, varying from 35% in the interior to 71 % in the coastal area. The diurnal variation in relative humidity during this period is maximum and ranges from 4 to 16%, depending upon the proximity of the sea. The relative humidity in the monsoon period rises to about 85% for the state. The variation in this period is minimum.

14.4.1.4.3 Rainfall

The average annual rainfall of the state is approx. 3000 mm, the bulk of which (70%) is received during the South-West monsoon which sets in by June and extends up to September. Approx. 90% of the total annual rainfall is received during the southwest and Northeast monsoon period. The actual rainfall received during Southwest monsoon last year (from 1st June 2019 to 30th September 2019) was 2309.8 mm as against the normal total rainfall of 2924.3 mm during the years. Annual rainfall and month wise breakup for the 2012 to 2018 is given in Table 14-8.

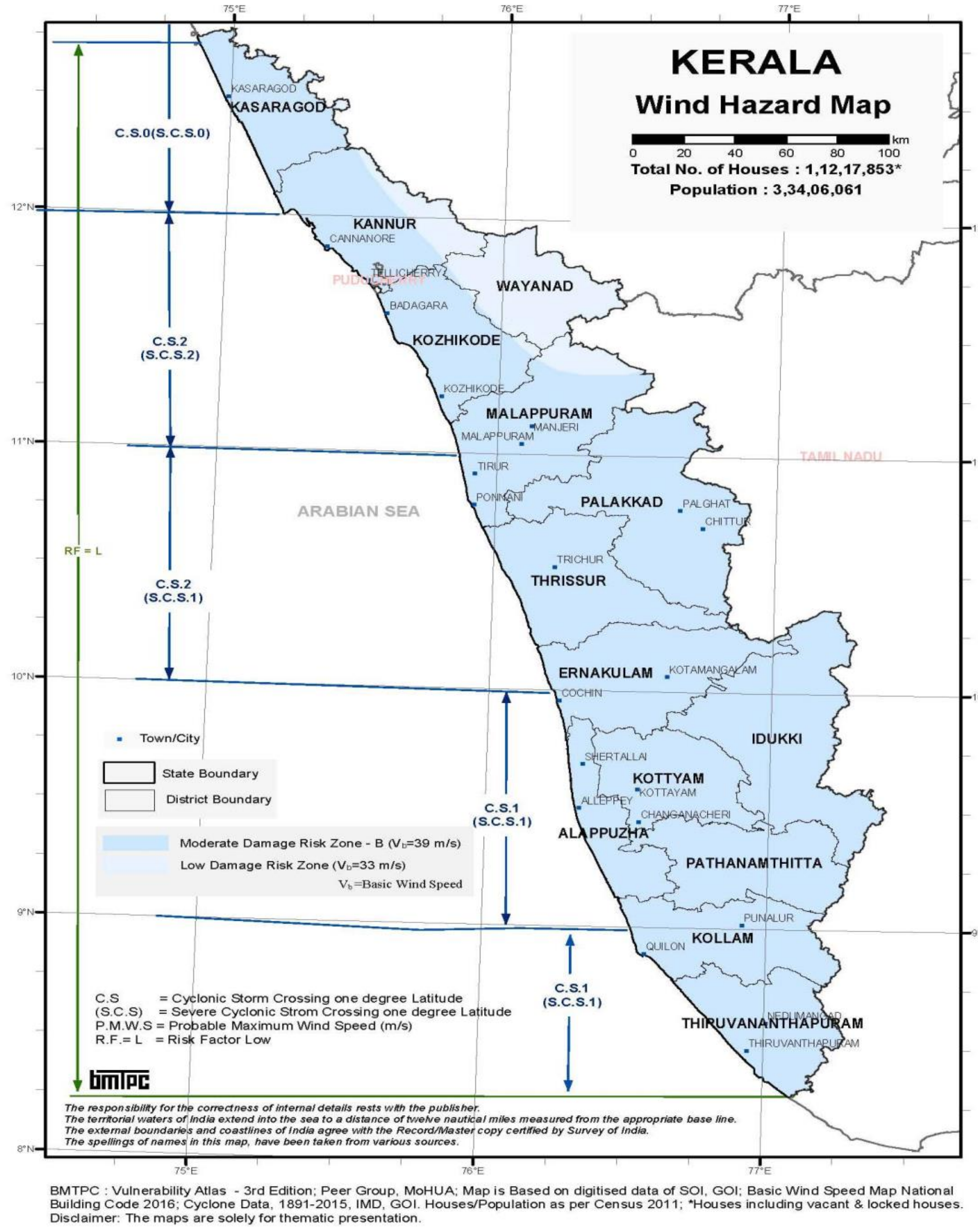
Table 14-8: Kerala Monthly and Annual Rainfall (in mm): 2012 - 2018

Year	Month												Total for the year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2012	7.4	9.1	29.6	197.5	83.8	444.6	360.6	502.6	240.0	189.3	113.4	9.7	**2187.6**
2013	3.9	40.1	49.9	49.3	119.3	1042.7	830.2	369.7	318.6	259.9	154.9	17.0	**3255.5**
2014	4.6	10.3	17.9	95.7	251.0	454.4	677.8	733.9	298.8	355.5	99.5	47.2	**3046.6**
2015	3.1	5.8	50.1	214.0	201.8	563.8	406.2	252.2	293.4	309.9	223.2	79.5	**2603.0**
2016	3.0	16.4	22.4	33.3	258.4	595.7	441.5	231.0	84.1	105.1	57.9	22.0	**1870.8**
2017	12.7	0.3	87.8	52.8	213.3	579.8	378.5	462.6	435.5	228.0	152.1	61.4	**2664.8**
2018	2.1	15.0	47.5	117.6	356.7	750.0	858.0	822.4	85.6	305.4	131.4	27.2	**3518.9**
Monthly Average	**5.2**	**13.6**	**43.7**	**110.6**	**210.0**	**632.9**	**564.6**	**482.0**	**251.2**	**250.8**	**137.3**	**38.7**	**2735.3**

Source: Indian Meteorological Department

14.4.1.4.4 Wind

In Kerala, the distribution pattern of calm days indicates that the inland stations experience more calm days due to the sheltering effects of the Western Ghats. The wind speed is highest during the south-west monsoon, the direction being from the northwest. The average wind speed during south west monsoon (June to Sept) period is 35 km/h, frequently raising up to 45 to 55 km/h. In general, the wind speed decreases from November to April. Generally, wind from the north east and east prevails in the morning (8.30 hrs), while in the afternoon (1730 hrs) it is from the west and northwest. This is clearly attributable to the effects of land and sea breezes. The average wind speed during North East monsoon (October to December) prevails around 20 km/h. During the cyclonic period wind speed often exceeds 100km/h. According to the wind hazard map of Kerala, about 96.9% of the total area in the Kerala state lies in the 140.4 km/h wind zone which is classified as Moderate Damage Risk Zone by the Building Materials & Technology Promotion Council (BMTPC) while the remaining area lies in 118.8 km/h wind zone. The entire Silver Line alignment falls under the Moderate Damage Risk Zone – B. The wind hazard map of Kerala is presented in Figure 14-1.


KERALA
Wind Hazard Map
0 20 40 60 80 100 km
Total No. of Houses : 1,12,17,853*
Population : 3,34,06,061
C.S.0(S.C.S.0)
C.S.2
(S.C.S.2)
C.S.2
(S.C.S.1)
C.S.1
(S.C.S.1)
C.S.1
(S.C.S.1)
RF = L
KASARAGOD
KANNUR
CANNANORE
TELLICHERRY
WAYANAD
BADAGARA
KOZHIKODE
MALAPPURAM
MANJERI
TIRUR
PONNANI
PALAKKAD
PALGHAT
CHITTUR
TRICHUR
THRISSUR
ERNAKULAM
KOTAMANGALAM
COCHIN
IDUKKI
SHERTALLAI
KOTTYAM
KOTTAYAM
ALLEPPEY
CHANGANACHERI
ALAPPUZHA
PATHANAMTHITTA
PUNALUR
QUILON
KOLLAM
NEDUMANGAD
THIRUVANANTHAPURAM
THIRUVANTHAPURAM
ARABIAN SEA
TAMIL NADU
PUDUCHERRY
Town/City
State Boundary
District Boundary
Moderate Damage Risk Zone - B (Vb=39 m/s)
Low Damage Risk Zone (Vb=33 m/s)
Vb=Basic Wind Speed
C.S = Cyclonic Storm Crossing one degree Latitude
(S.C.S) = Severe Cyclonic Strom Crossing one degree Latitude
P.M.W.S = Probable Maximum Wind Speed (m/s)
R.F.= L = Risk Factor Low
bmtpc
The responsibility for the correctness of internal details rests with the publisher.
The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The external boundaries and coastlines of India agree with the Record/Master copy certified by Survey of India.
The spellings of names in this map, have been taken from various sources.
75°E
76°E
77°E
12°N
11°N
10°N
9°N
8°N

BMTPC : Vulnerability Atlas - 3rd Edition; Peer Group, MoHUA; Map is Based on digitised data of SOI, GOI; Basic Wind Speed Map National Building Code 2016; Cyclone Data, 1891-2015, IMD, GOI. Houses/Population as per Census 2011; *Houses including vacant & locked houses.
Disclaimer: The maps are solely for thematic presentation.

Figure 14-1: Wind Hazard Map of Kerala

14.4.1.5 Forest

Forest cover of Kerala is largely spread over the Western Ghats which border the state. The recorded forest area is 11521.813 km². This includes 9195.735 km² reserve forests, 291.575 km² is proposed and 1766.795 km² vested forest. The total plantation area accounts approx. 13% of the total forest area. The percentage of forest cover in Kerala is 29.65 which is higher than the national coverage of 21.67%. During the period 1st January 2015 to 5th February 2019, a total of 15.82 hectares of forest land was diverted for non-forestry purposes under the Forest Conservation Act, 1980

(MoEF&CC, 2019). Forest Cover in the State has increased by 823.29 km^2 as compared to the previous assessment reported in 2017. District wise forest cover in Kerala are presented in Table 14-9.

Table 14-9: District wise Forest Cover, Kerala

District	Geographical Area (GA) in km^2	Forest Cover in km^2 (2019 Assessment)				% of GA
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total	
Thiruvananthapuram	2,189	57.00	697.88	549.05	1,303.93	59.57
Kollam	2,483	104.00	657.25	561.26	1,322.51	53.26
Pathanamthitta	2,652	161.95	1,235.81	557.76	1,955.52	73.74
Alappuzha	1,415	0.00	27.00	52.90	79.90	5.65
Kottayam	2,206	12.00	531.95	560.34	1,104.29	50.06
Idukki	4,356	348.36	1,795.63	1,006.66	3,150.65	72.33
Ernakulam	3,063	167.01	615.03	583.67	1,365.71	44.59
Thrissur	3,027	218.86	475.81	464.55	1,159.22	38.30
Palakkad	4,482	403.36	636.72	1,043.51	2,083.59	46.49
Malappuram	3,554	142.59	424.08	1,414.66	1,981.33	55.75
Kozhikode	2,345	70.81	409.89	956.27	1,436.97	61.28
Wayanad	2,130	188.99	1,221.00	170.23	1,580.22	74.19
Kannur	2,961	58.00	485.88	1,110.09	1,653.97	55.86
Kasaragod	1,989	1.90	294.31	670.27	966.48	48.59
Total	**38,852**	**1,934.83**	**9,508.24**	**9,701.22**	**21,144.29**	**54.42**

Source: Forest Survey of India

14.4.1.6 Drainage Pattern

Out of Kerala ‘s 44 rivers, 41 flow westwards and the rest towards east. The basin area of major rivers is located within the Western Ghats, a global biodiversity hotspot, while some other northern rivers originate in laterite hills. The short length of the rivers coupled with very high population density (over 30 million people living in a land area of 38,000km2) creates high dependency on water and the rivers susceptibility towards environmental onslaughts. The total water availability as average annual stream flow is 6,357 MCM/annum from 34 major and minor rivers.

As per a survey by CWRDM (1988), a total of 236 springs were identified in the state. About 80% of these springs are situated in the eastern side of the Western Ghats belt of the state.

14.4.1.7 Soil

Kerala is endowed with a variety of soils due to the climate, topography, and vegetation characteristics. Laterite and loams form the major soil types of Kerala. The other soil types developed as a result of agro-climatic variations include riverine and coastal alluvium, black soils, and problem soils like acid saline, hydromorphic, and greyish Onattukara. Soil Types of Kerala is shown in Figure 14-2.

14.4.1.7.1 Laterite Soil

Majority of area comprises this type of soil. Heavy rainfall and high temperature are conducive for laterization. Laterites are poor in available Nitrogen (N) and Phosphorus (P), low in water holding capacity and cation exchange capacity (CEC).

14.4.1.7.2 Coastal Alluvial Soil

Seen in the coastal tracts along the west, they have been developed from recent marine deposits. More permeability, low organic matter content, low CEC and less Water holding capacity characterizes the coastal alluvial soil.

14.4.1.7.3 Riverine Alluvial Soil

Seen along the banks of rivers, shows wide variation in physio-chemical properties depending on the nature of alluvium and the characteristic of the catchment area through which the river flows. Organic Matter, N and Potassium (K) are moderate.

14.4.1.7.4 Red Soil

The red colour of soil is due to the presence of Fe_2O_3, mainly localized in southern parts of Thiruvananthapuram. The soil is almost homogeneous. Acidity ranges from 4.8 to 5.9. The gravel content is comparatively less. Low in essential nutrients and organic matter.

14.4.1.7.5 Black Soil

The black soils are mainly found in the north eastern part of Palakkad district. It is dark in colour, low in organic matter, calcareous, moderately alkaline (pH 8.0) and high in clay content. As this soil promotes cotton cultivation, it is also known by the name of black cotton soil. Other major crop that can be grown on this soil are Rice, Sugarcane, Jowar, Ragi and Oil Seeds.

14.4.1.7.6 Forest Soil

A product of weathering of crystalline rocks under forest cover. Rich in organic carbon. pH acidic. Rich in N and poor in P.

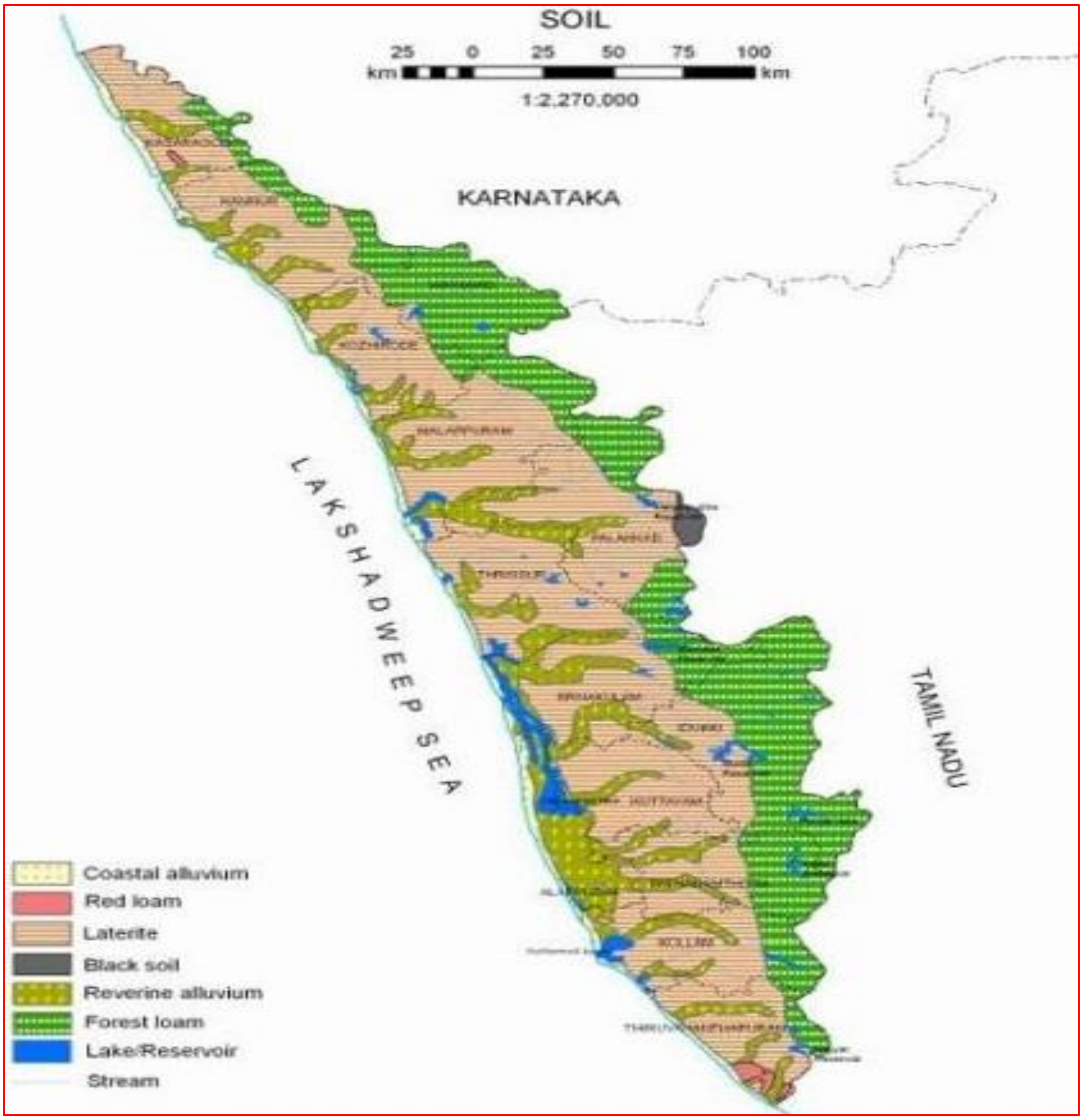
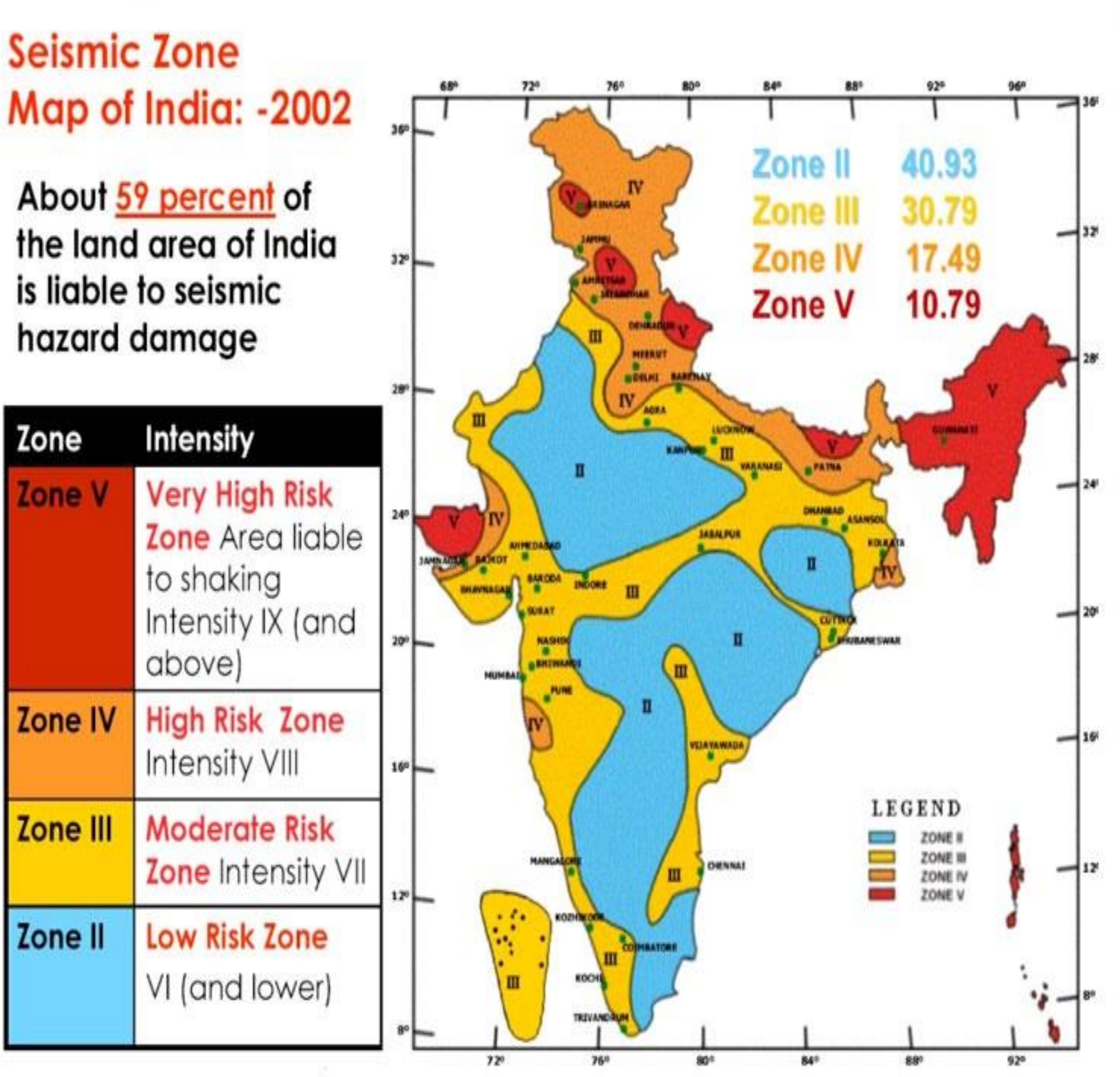


Figure 14-2: Soil Types of Kerala

14.4.1.8 Seismicity

Based on tectonic features and records of past earthquakes, a seismic zoning map of India has been prepared by a committee of experts under the auspices of Bureau of Indian Standard (BIS Code: IS: 1893: Part I 2002. According to the seismic-zoning map of India, the project area falls in Zone III of seismicity signifying moderate-risk of earthquake. The seismicity map of study area is shown in Figure 14-3.



Seismic Zone Map of India: -2002

About 59 percent of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area liable to shaking Intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone Intensity VII
Zone II	Low Risk Zone VI (and lower)

Zone II	40.93
Zone III	30.79
Zone IV	17.49
Zone V	10.79

Figure 14-3: Seismic Zonation and Intensity Map of India

14.4.1.9 Natural Hazards and Vulnerability

The state of Kerala is vulnerable to a multitude of hazards and is categorized as a multiple-hazard prone state. The state experiences various kinds of disasters of recurrent nature that results in loss of life, livelihood and property, and disruption of economic activity, besides causing immense hardship to the affected population. Flood, coastal erosion, landslides (debris flows) and lightening are the most commonly occurring natural hazards in Kerala.

14.4.1.9.1 Floods

In Kerala, riverine flooding is a recurring event consequent to heavy or continuous rainfall exceeding the absorptive capacity of soil and flow capacity of streams and rivers. This causes the water course to overflow its banks onto flood plains. These flood plain by definition is a relatively flat land adjacent to a natural water course, composed primarily of unconsolidated depositional material derived from sediments transported by the related stream and subjected to periodic flooding. Reclamation and settlement in floodplain areas is a major cause of damage due to floods in Kerala.

The most affected areas in last flood 2018 were Aluva and Paravoor in Ernakulam district, Ranni and Pandalam in Pathanamthitta district, Kuttanad and Chengannur in Alappuzha district, Mananthavady and Panamaram in Wayanad district, and Munnar and Cheruthoni in Idukki district. The District level flood prone area in sq.km and in percentage are presented in below Table 14-10.

Table 14-10: Flood prone area in each district

District	Area km²	Area%	District	Area km²	Area%
Thiruvananthapuram	268.09	12.23	Idukki	38.78	0.89
Kollam	283.62	11.41	Thrissur	688.44	22.65
Alappuzha	762.57	53.77	Malappuram	601.67	16.93
Pathanamthitta	212.76	8.00	Palakkad	567.16	12.66
Kottayam	461.33	20.95	Kozhikkode	288.83	12.30
Ernakulam	718.94	23.50	Wayanad	215.39	10.11
Kannur	339.18	11.45	Kasaragod	198.79	9.99

Source: CESS, 2010. Plan Project 249 for taluk wise area

14.4.1.9.2 Landslides

The term landslide includes a broad range of different types of motion whereby earth material is dislodged by falling, sliding and flowing under the influence of gravity. In fact, mass movements such as landslides are natural phenomenon that causes landscape changes, threat to life and destruction of property. The most common type of landslides in Kerala is debris flows. Landslides in Kerala commonly occur in localised areas of the Western Ghats region where the slope is steep and the soil is over saturated as a result of prolonged rainfall. The slope in the Western Ghats region is generally steep to very steep with plateau edges highly indented having >25° slope. The study reveals that 1848 km² or 4.75% of the state is under high and 3759 km² or 9.67% under low hazard category. Devikulam, Vythiri, Nilambur, Mannarkad and Ranni are the most landslide prone taluks in the state.

14.4.1.9.3 Tsunami

A tsunami is a series of ocean waves that sends surges of water, sometimes reaching heights of over 100 feet (30.5 meters), onto land. These walls of water can cause widespread destruction when they crash ashore.

The Kerala coast located in the shadow zone with respect to the direction of propagation of the tsunami, encountered unexpected devastation on 26th December 2004. Although tsunami affected parts of Kerala coast, maximum devastation was reported in the low coastal land of Kollam, Alleppey and Ernakulam districts, particularly a strip of 10 km in Azhikkal, Kollam district. The tsunami waves attained heights of 3m to 5m and inundated the coastal areas at different times. Figure 14-4 shows the time of maximum inundation at different locations, Kerala coast.

This varying effect along the coast could be attributed to local amplification of tsunami waves in certain regions. About 176 people were killed and 1600 injured in the coastal belt. Further, the tsunami reached 187 villages affecting nearly 25 lakh persons in Kerala.

As many as 6280 dwelling units were uprooted, 11175 were partially damaged and nearly 84773 persons were evacuated from the coastal areas and accommodated in 142 relief camps after tsunami.

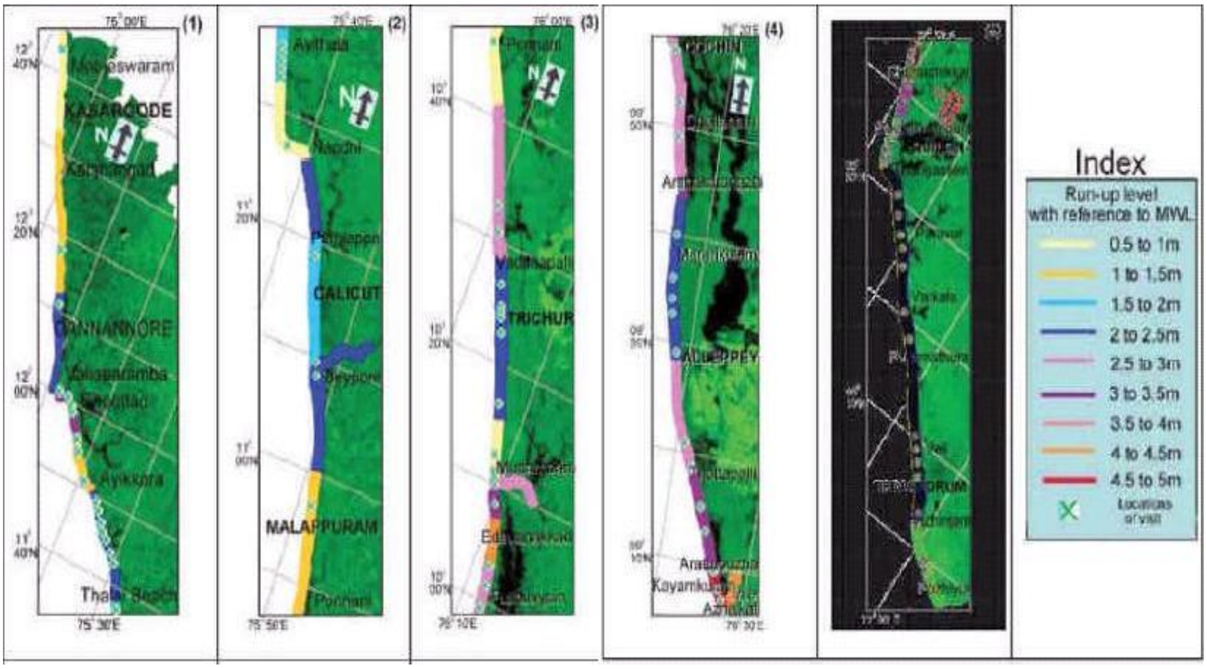


Figure 14-4: Tsunami run-up level along the Kerala

14.4.1.9.4 Coastal hazards

In Kerala, out of the total 14 districts, 9 districts are bordering the sea coasts which are too vulnerable to floods, cyclones, High waves, Storm surges, Kalla kadal, Tsunami, coastal erosion and landslide etc. Natural causes of coastal erosion are due to the action of waves, winds, tides, near shore currents, storm surges and sea level rise. The mean maximum storm surge height in the state is 3.5 m and minimum is 2.3 m. If the storm surge is during high tide, the maximum surge height in the state will be 4.2 m and minimum storm height will reach up to 3 m, as observed by the Meteorological Department, Thiruvananthapuram.

“Kalla kadal” is a Malayalam word having literal meaning of 'sea thief' which is used to represent a phenomenon that occurs during the pre-monsoon season and monsoon breaks along Kerala coast, which was adopted by UNESCO to refer to sea creeping into coast because of swells generated by storms generated near Antarctica. This phenomenon occurs mostly during pre-monsoon season and sometimes during post monsoon and continues for a few days inundating low lying coasts. During high tides the water level can reach 3-4 m above Maximum Water Level (MWL). The tide levels for several locations along the Indian coast has analysed and It is observed that the Highest High Water is about 1.5 m at Kochi. The tides of Kerala are mixed, semidiurnal in nature and occur within the microtidal range (<2m). Eroding sectors along the coast in each District, Taluk and whole State is presented in Table 14-11.

Table 14-11: Eroding sectors along the coast in each District, Taluk and whole State

Sl. No.	District	Length		Length		Length	
		Km	%	Km	%	km	%
		High (without sea wall)		High (with Sea wall)		Low	
1	Thiruvananthapuram	11.9	15.86	15.66	20.88	30.84	41.11
2	Kollam	1.14	2.34	37.77	77.58	0.91	1.86
3	Alappuzha			29.98	37.84	3.7	4.67
4	Ernakulam			33.39	69.02		
5	Thrissur	2.58	3.43	17.37	23.16	0.98	1.3
6	Malappuram			15.4	31.63	6.44	13.23
7	Kozhikode			35.4	44.68	8.47	10.69
8	Kannur			9.33	14.27	17.38	26.58
9	Kasaragod	1.3	1.47	4.34	4.93	28.31	32.15
	Total	**16.91**	**3.02**	**198.63**	**35.47**	**97.02**	**17.33**

Source: CESS, 2010. Plan Project 249 for taluk wise area

14.4.1.9.5 Lightning

Lightning is a common weather phenomenon in Kerala and on an average about 70 people die in the State due to lightning every year. The Cumulonimbus (Cb) clouds usually form and produce lightning in the State usually in the months of April & May and again in October & November. Analysis of the 17 years data (1986 to 2002) indicated that 83% of the lighting events happened between 3 pm and 5 pm. The frequency and distribution of lightning incidence is more in the mid lands of Kerala followed by low lands.

14.4.1.10 Climate Change

Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events.

The UNFCC report provides a comprehensive assessment of sea level rise and its causes, Given current concentrations and ongoing emissions of greenhouse gases, it is likely that the end of this century will see a 1–2° C increase in global mean temperature above the 1990 level (about 1.5–2.5° C above the pre-industrial level). The world's oceans will warm, and ice melt will continue. Average sea level rise is predicted to be 24–30 cm by 2065 and 40–63 cm by 2100 relative to the reference* period of 1986–2005. Most aspects of climate change will persist for many centuries, even if emissions are stopped.

According to the Indian Network for Climate Change Assessment (INCCA), Kerala is the one of most vulnerable region in the country due to the projected sea level rise. The sea level is on the rise due to global warming and the projected Sea Level Rise (SLR) along Kerala coast on a conservative estimation is about 100 to 200 mm over the next 100 years. If the sea level rises by one metre, 169 sq. km of the coastal region surrounding Kochi will be inundated. Hence the impact on the project will also be felt in the areas where the Silver Line alignment is closer to the coastal region. The proposed Silver Line rail corridor is passing closer to sea near existing Bekal Fort IR railway station area, which is about 200 m away from the sea. However, keeping in mind to mitigate the climate impact the Silver Line rail level in this area is planned approx. 5m above the MSL.

14.4.1.11 Air Environment

14.4.1.11.1 Ambient Air Quality

Air quality in India is governed by the National Ambient Air Quality Standards (NAAQS) formulated under the Air (Prevention and Control of Pollution) Act, 1981 by Central Pollution Control Board (CPCB). Pollutants that have established national standards are referred to as "criteria pollutants." As a part of this study ambient air quality monitoring (AAQM) has been carried out by setting up ambient air quality monitoring stations at 10 locations. Pollutants considered for the proposed Silver Line rail corridor project are Particulate Matter (PM_{10}), Fine Particulate Matter ($PM_{2.5}$), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and Carbon Monoxide (CO).

The baseline data pertaining to the existing air quality will help mitigate impact on air-quality during construction stage and operation stage of the project. The prominent source of anthropogenic air pollution in urban area is vehicular traffic, industrial emissions, domestic fuel burning, construction and demolition activities etc.

Monitoring has been carried out at 10 locations along the project corridor areas as per the guidelines for Ambient Air Quality Monitoring, National Ambient Air Quality Monitoring Series NAAQMS/25/2003-04. The ambient air quality monitoring was conducted in November 2019 – January 2020 (post monsoon season in Kerala) during baseline survey to assess the ambient air quality status along the proposed alignment.

The Particulate Matter (PM_{10} & $PM_{2.5}$), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Carbon Monoxide (CO) levels at all monitoring locations in the project corridor areas were well within the prescribed National Ambient Air Quality Standards. The selected locations of ambient air quality monitoring stations are presented in Table 14-12 and the summary of Ambient Air Quality results is presented in Table 14-13.

Table 14-12: Ambient Air Quality Monitoring Stations/Location

Sl. No.	Location Code	Location	GPS Coordinates	Area Category
1	AAQ1	Kochuveli, Thiruvananthapuram	8°30'42.5" N; 76°54'05.2" E	Commercial
2	AAQ2	Kollam	8°54'05.6" N; 76°39'37.0"E	Residential
3	AAQ3	Chengannur	9°20'20.6” N 76°38'36.3" E	Residential
4	AAQ4	Kottayam	9°34'50.32” N 76°32'32.1" E	Commercial cum residential
5	AAQ5	Ernakulam	10°00'51.9” N 76°21'49.7" E	Commercial
6	AAQ6	Thrissur	10° 31' 36.9" N 76° 13' 52.7" E	Residential
7	AAQ7	Tirur	10° 55' 33.8" N 75° 54' 57.7" E	Residential
8	AAQ8	Kozhikode	11° 15' 37.7" N 75° 46' 20.8" E	Residential
9	AAQ9	Kannur	11° 52' 42.2" N 75° 22' 20.1" E	Commercial
10	AAQ10	Kasaragod	12° 29' 11.5" N 74° 59' 26.6" E	Residential

Table 14-13: Ambient Air Quality Data in different districts along the corridor

Sl. No.	Location Code	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)			SO_2 (µg/m^3)			NO_2 (µg/m^3)			CO (mg/ m^3)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	AAQ1	55.67	67.92	62.96	20.85	34.44	27.37	<4	8.49	<4	8.55	15.25	11.61	0.32	0.40	0.36
2	AAQ2	30.02	44.68	36.94	11.13	22..03	15.48	<4	7.0	<4	<6	16.34	9.98	0.26	0.38	0.33
3	AAQ3	26.44	44.95	36.65	7.0	22.59	15.81	<4	7.17	<4	<6	<6	<6	0.30	0.36	0.32
4	AAQ4	55.16	80.54	67.81	22.41	37.10	29.90	6.99	24.32	11.93	12.43	24.15	18.07	0.33	0.42	0.37
5	AAQ5	25.19	48.43	34.22	8.31	18.28	13.12	<4	7.05	<4	6.81	14.71	10.76	0.30	0.38	0.33
6	AAQ6	48.50	62.30	53.13	20.1	33.2	26.39	<4	8.70	5.27	6.1	10.2	7.06	0.40	1.10	0.76
7	AAQ7	38.90	50.30	46.13	16.3	26.7	22.57	<4	7.2	4.17	<6	7.20	<6	0.30	0.90	0.66
8	AAQ8	35.60	54.30	48.60	10.3	30.2	22.78	<4	7.10	<4	<6	7.20	<6	0.40	0.90	0.69
9	AAQ9	39.60	49.60	44.06	15.4	24.3	20.40	<4	5.90	<4	<6	7.20	<6	0.40	0.90	0.69
10	AAQ10	39.40	52.30	47.79	17.40	30.1	23.13	<4	6.80	<4	<6	8.30	<6	0.50	0.90	0.68
NAAQS Limit		**100**			**60**			**80**			**80**			**04**		

Source: Primary survey by EIA Study Team

14.4.1.11.2 Ambient Noise Quality

The unwanted sound is known as noise and is measured in decibel (dBA). Noise can originate from a variety of sources. Some of the manmade sources of noise generation are industries, domestic sources, transport and traffic, construction activities, festivals and religious activities etc.

Noise is an important environmental attribute in all transportation projects. In respect to Silver Line rail corridor, associated construction activities like movement of construction vehicle/machineries, tunnelling, piling, drilling and excavation are the main source of noise during the construction phase. In operation phase movements of trains is a source of noise pollution.

Environmental Quality Standards for Shinkansen Super Express Railway (Japan) noise standards are presented in Table 14-14. The standards for regulating the environmental conditions of Shinkansen Super Express Railway noise are established to preserve the living environment and to contribute to protecting people's health.

Ambient noise quality was monitored at 22 locations, including all stations along the entire Silver Line rail corridor to characterize the baseline noise levels in November to December 2019. The ambient noise quality monitoring locations and ambient noise quality of study area are presented in Table 14-15 and Table 14-16 respectively. The Leq day, and Leq night calculated for various locations in the area are compared with the national standards prescribed by CPCB for various zones. The ambient noise quality results show Leq Day time varies from 44.7 to 68.7 dB(A) and Leq Night time varies from 36.5 to 59.2 dB(A). The National Ambient Noise Quality standards laid down by CPCB has been given in Table 14-17.

Table 14-14: Env. Quality Standards for Shinkansen Super Express Railway Noise

Category of Areas	Standard Value (dB)
I	70 or less
II	75 or less
Note: Area category I refer to areas used mainly for residential purpose and area category II refers to other areas, including commercial and industrial areas, where the normal living conditions shall be preserved.	

Source: MOE, Govt. of Japan

Table 14-15: Ambient Noise Quality Monitoring Location

Sl. No.	Location Code	Location	GPS Coordinates	Area Category
1	N1	Kochuveli, Thiruvananthapuram Railway Station	N 8^{0}30'44.88" E 76^{0} 53' 53.43"	Residential
2	N2	Near Technopark, Thiruvananthapuram	N 8^{0}32'54.80" E 76^{0} 52' 47.10"	Commercial
3	N3	Near to Kaniyapuram Railway Station	N 8^{0} 35',2.38" E 76^{0} 51' 27.95”	Residential
4	N4	Kollam, Mukathala	N 8^{0} 53'40.55" E 76^{0} 39'27.09"	Residential
5	N5	Nooranad Guest House	N 9^{0}10’2.126” E 76^{0}38’23.082”	Commercial
6	N6	Chengannur Railway Station (Proposed)	N 9^{0} 20’19.39” E 76^{0}38’39.02”	Residential
7	N7	Near Govt. Hospital, Manarcaud	N 9^{0} 30’44.785” E 76^{0}34’8.14”	Silence Zone
8	N8	Muttampalam, Kottayam	N 9^{0} 34’39.814” E 76^{0}32’23.85”	Residential
9	N9	Near Nursing College, Piravom	N 9^{0} 10’2.126” E 76^{0}38’23.082”	Silence Zone
10	N10	Near BPCl, Irumpanam	N 9^{0} 20’19.39” E 76^{0}38’39.02”	Commercial
11	N11	Near Sanskara School, Kakkanad	N 10^{0} 0’ 36.249” E 76^{0} 22’ 38.106”	Silence Zone
12	N12	Info park, Kakkanad	N 10^{0} 0’52.2” E 76^{0} 21’48.4”	Commercial
13	N13	Cochin International Airport area	N 10^{0} 09’ 34.097” E 76^{0} 22’ 58.916”	Commercial

Sl. No.	Location Code	Location	GPS Coordinates	Area Category
14	N14	Thrissur Railway Station (Proposed)	N 10° 30' 32.1336" E 76° 12' 23.9472"	Residential
15	N15	Pookunnam School, Tirur – Kuttipuram Rd	N 10° 30' 33.1956" E 76° 12' 25.7472"	Silence Zone
16	N16	Tirur Railway Station (Proposed)	N 10° 55' 40.7748" E 75° 54' 41.8608"	Residential
17	N17	Kadalundi	N 11° 7' 47.0532" E 75° 49' 53.5872"	Residential
18	N18	Kozhikode Railway Station (Proposed)	N 11° 14' 41.5248" E 75° 46' 49.3968"	Residential
19	N19	South L P school, Kothamangalam	N 11° 26' 6.3744" E 75° 42' 7.3512"	Silence Zone
20	N20	Kannur Railway Station, (Proposed)	N 12° 9' 16.7652" E 75° 10' 37.8624"	Residential
21	N21	Kalanad Railway Station	N 12° 27' 55.566" E 74° 59' 55.1076"	Commercial
22	N22	Kasaragod Railway Station (Proposed)	N 11° 7' 50.7936" E 75° 49' 44.652"	Residential

Table 14-16: Ambient Noise Quality of Study Area

Sl. No.	Location Code	L_{10}	L_{50}	L_{90}	L_{Max}	L_{Min}	L_{DN}	L_{Day}	L_{Night}
1	N1	57.6	50.4	42.3	65.5	41.1	54.5	54.5	44.4
2	N2	71.2	65.7	52.9	78.7	48.8	68.7	68.4	59.2
3	N3	56.4	48.0	42.0	72.6	36.0	53.4	51.6	45.4

4	N4	59.0	48.0	42.0	69.7	35.0	53.9	53.4	44.5
5	N5	56.9	49.0	41.3	59.9	35.0	52.7	52.3	43.3
6	N6	56.5	47.8	40.9	61.2	36.1	51.8	51.5	42.2
7	N7	56.6	49.2	41.9	60.5	38.5	53.0	51.9	44.5
8	N8	56.6	50.8	41.3	63.2	38.5	53.8	53.5	44.3
9	N9	58.1	50.8	40.7	65.5	39.6	53.9	54.7	42.0
10	N10	55.3	48.1	40.7	63.7	39.2	52.4	52.0	43.1
11	N11	48.6	43.1	40.4	60.7	38.6	49.3	45.2	42.3
12	N12	63.9	56.8	46.5	74.1	35.0	61.4	59.7	53.4
13	N13	61.7	58.8	56.7	82.3	54.9	66.1	59.8	58.9
14	N14	59.4	50.5	40.6	66.0	38.4	51.0	54.4	43.1
15	N15	78.6	61.2	44.4	80.4	40.2	61.6	68.0	46.1
16	N16	53.0	48.4	36.4	56.5	35.0	49.8	50.1	37.5
17	N17	56.8	49.6	40.0	58.1	38.6	49.3	51.6	43.5
18	N18	70.2	58.9	50.2	74.2	46.0	60.0	62.8	53.2
19	N19	59.6	41.4	36.4	64.2	35.1	45.6	48.8	37.9
20	N20	60.4	50.4	35.2	66.8	34.0	49.8	54.8	37.4
21	N21	49.2	46.4	35.2	51.2	34.8	43.7	44.7	36.5
22	N22	73.1	64.2	52.1	82.1	44.1	64.2	67.4	56.3

Source: Primary survey by EIA Study Team

Table 14-17: National Standards for Ambient Noise

Area Code	Category of Area	Limits in Decibel (dB A) Leq	
		Day Time*	Night Time*
A	Industrial	75	70
B	Commercial	65	55
C	Residential	55	45
D	Silence Zones**	50	40

Source: CPCB guideline (as per The Noise Pollution (Regulation and Control) Rules, 2000)

Note: * Daytime: 6 AM to 10 P.M., Night-time 10 PM to 6 AM;
**Silence zone is an area up to 100 m around premises as hospitals, educational institutions and courts.

14.4.1.11.3 Vibration

Human response to vibration is subjective and will be different for different people. When the vibrations reach the floors and walls it may result in perceptible vibration depending on the amplitude and frequency of the vibrations. Rattling of windows, dishes, and similar parts may also result in audible noise which is called ground-borne noise. People may be more annoyed if they are exposed to both noise and vibration compared to when only vibration is felt.

The sources of the vibration and noise are due to construction of tunnel. Vibration induced by the silver line train during operation is mainly due to the rolling stock, track and the interaction between them. Continuous effect of vibration on the buildings can cause damage to buildings. Building subjected to the vibration effect with more than 10 mm/s would receive structural damage. Historic buildings are more susceptible to vibration effect with more than 5 mm/s. The vibration induced by the operation of train first causes the vibration of track structure as well as tunnel structure, and then, propagate through the strata to the surrounding environment. The criteria for vibration effects from construction activities in four different categories of buildings and the criteria for acceptable ground-borne vibrations (GBV) and ground-borne noise (GBN) from high speed train operation in terms of the three land use categories are presented in Table 14-18 and Table 14-19 respectively.

Table 14-18: Construction Vibration Damage Criteria

Building Category	PPV (inch/sec)	Approximate L_V*
Reinforced concrete, steel, or timber (no plaster)	0.5	102
Engineered concrete and masonry (no plaster)	0.3	98
Non-engineered timber and masonry buildings	0.2	94
Buildings extremely susceptible to vibration damage	0.12	90

** Root mean square vibration velocity level in VdB relative to 1 micro-inch/second.* *Source: FTA (2006)*

Table 14-19: Ground-Borne Vibration and Ground-Borne Noise Impact Criteria

Land Use Category	GBV Impact Levels (VdB re 1 µin/s)			GBN Impact Levels (dB re 20 µPa)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]	N/A[5]	N/A[5]	N/A[5]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

Notes: *Source: FTA (2006)*

1. “Frequent Events” is defined as more than 70 vibration events of the same kind per day.
2. “Occasional Events” is defined as between 30 and 70 vibration events of the same kind per day.
3. “Infrequent Events” is defined as fewer than 30 vibration events of the same kind per day.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5. Vibration-sensitive equipment is not sensitive to ground-borne noise.

Construction activities usually produce vibration levels that may disturb people living nearby. Blasting below the surface would produce lower vibration levels at a receptor due to additional attenuation provided by distance and transmission through soil and rock. The ground borne vibration impacts may be perceptible to people who are outdoors but does not cause a strong adverse human reaction. Table 14-20 shows the recommended typical levels of vibration for construction equipment by FTA. Based on reference values of vibration at 25 feet, an impact at 75 feet, 100 feet and 150 feet are calculated.

Table 14-20: Typical Levels of Vibration for Construction Equipment

Construction Activity	VdB at 25 Feet	VdB at 75 Feet	VdB at 100 Feet	VdB PPV at 150 Feet
Rock drilling	115.9	101.6	97.9	94.3
Dump trucks	122.7	108.3	104.6	99.3
Bulldozer	124.0	109.7	106.0	100.7
Excavator 0.089, 106	124.0	109.7	106.0	100.7
Crane 0.808, 87	143.2	128.9	125.1	119.8

Source: FTA, 2006

14.4.1.12 Water Environment

Water environment encompasses assessment of surface and ground water quality and quantity available in the region. This assessment is required from the point of view of assessment of water resource need during the various phases of project and impact of the proposed activities on these resources as groundwater and surface water is proposed to be used during construction and operation phase of the project.

14.4.1.12.1 Water Resources

Kerala is gifted with rich resources of freshwater bodies. The state has a total freshwater area of 1, 58,358 ha, consisting of reservoirs (42,890 ha), private ponds (21,986 ha), irrigation tanks (2,835 ha), freshwater lakes (1,620 ha), panchayat ponds (1,487 ha), village ponds and other water holds (1,317 ha), and check dams, bunds, barriers or anicuts (1,138 ha). The state has 41 west-flowing and 3 east-flowing rivers, constituting an area of 85,000 ha. The average annual stream flow from various rivers/surface water bodies flowing through different districts of the state. Kerala receives an average annual rainfall of 3049 mm, partly appears as stream flow and rest contributes in groundwater recharge. Central Ground Water Board (CGWB) estimated the groundwater availability of the State as 4087.23 MCM/annum.

14.4.1.12.2 Surface Water Quality Assessment

To establish the baseline status of the existing sources of surface water along the Silver Line rail corridor, 12 samples were collected during the study period November to December 2019. The Surface water quality analyses were carried out with respect to various parameters like temperature, pH, conductivity, DO, BOD, total and fecal coliforms. The description of water quality monitoring locations and physico-chemical characteristics are presented in Table 14-21, Table 14-22 and Table 14-23 respectively. Based on these characteristics, surface water quality was compared with CPCB Standards for Water Quality Criteria under Class C (Drinking water source after conventional treatment and disinfection).

Table 14-21: Description of Surface Water Quality Monitoring Locations

Sl. No.	Location Code	Location	GPS Coordinates
1	SW1	Akulam Lake	N 8^{0}31’4.29” E 76^{0}53’33.67”
2	SW2	Vamanapuram River	N 8° 42’ 9.26” E 76° 47’ 56.41”
3	SW3	Kallada River	N 9° 1’ 38.17” E 76° 40’ 38.49”
4	SW4	Pampa River	N 9° 19’ 53.03” E 76° 38’ 35.34”
5	SW5	Periyar River	N 10° 7’ 17.297” E 76° 23’ 10.785”
6	SW6	Chalakudyppuzha	N 10° 13’ 28.658” E 76° 19’ 33.955”
7	SW7	Bhaathappuzha	N10° 51' 49.248" E 75° 58' 56.3988"
8	SW8	Kadalundipuzha	N 11° 7' 50.7936" E 75° 49' 44.652"
9	SW9	Beypore River	N 11° 10' 47.8452" E 75° 49' 42.8232"
10	SW10	Mahe River	N 11° 42' 15.7572" E 75° 32' 46.554"

Sl. No.	Location Code	Location	GPS Coordinates
11	SW11	Bakel River	N 12° 24' 30.8052" E 75° 1' 47.802"
12	SW12	Chandragiripuzha	N 12° 29' 31.1928" E 74° 59' 12.9228"

Table 14-22: Surface Water Quality of Study Area

Sl. No	Parameters	Units	SW1	SW2	SW3	SW4	SW5	SW6	IS 2296: 1992
1	pH value	-	7.19	7.29	7.16	6.86	7.24	7.57	6.0 – 9.0
2	Conductivity	µS/cm	1935	70	108	42	58	110	-
3	Total Suspended Solids	mg/l	6.2	BDL	3.4	BDL	4.6	BDL	-
4	Total Dissolved Solids	mg/l	905	32	32	19	26	53	1500
5	Total Alkalinity as CaCO3	mg/l	80.15	9.16	9.16	6.87	11.45	16.05	-
6	Total Hardness as $CaCO_3$	mg/l	170	10	12	8	12	28	-
7	Calcium as Ca	mg/l	36	3.2	3.2	2.4	3.2	8	-
8	Magnesium as Mg	mg/l	19.48	32	1.0	BDL	1.0	1.95	-
9	Chloride as Cl	mg/l	446.81	11.65	18.45	5.83	9.71	19.4	600
10	Sulphate as SO_4	mg/l	55.78	32	3.65	BDL	BDL	BDL	400
11	Fluoride as F	mg/l	0.1	0.15	0.19	BDL	BDL	BDL	1.5
12	Iron as Fe	mg/l	1.29	0.93	0.43	0.39	0.50	1.09	0.5
13	Nitrate as NO_3	mg/l	2.38	BDL	BDL	BDL	0.14	0.32	50

Sl. No	Parameters	Units	SW1	SW2	SW3	SW4	SW5	SW6	IS 2296: 1992
14	Phosphate as PO_4	mg/l	0.78	BDL	BDL	BDL	0.37	BDL	-
15	Sodium as Na	mg/l	305	7.8	11.1	5.5	6.1	6.7	-
16	Potassium as K	mg/l	22.9	6	5.7	3.7	4.1	3.3	-
17	Copper as Cu	mg/l	BDL	BDL	BDL	BDL	BDL	0.01	1.5
18	Manganese as Mn	mg/l	0.024	0.031	0.02	0.044	0.017	0.117	-
19	Cadmium as Cd	mg/l	0.001	0.001	0.001	BDL	BDL	0.001	0.01
20	Zinc as Zn	mg/l	BDL	BDL	0.029	BDL	0.026	0.139	15
21	Chromium as Cr	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05
22	Lead as Pb	mg/l	BDL	BDL	BDL	BDL	0.012	0.012	0.1
23	Nickel as Ni	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-
24	B O D (3 days at 27^{O} C)	mg/l	5.2	BDL	BDL	BDL	2.6	BDL	3
25	C O D	mg/l	12	BDL	BDL	BDL	12	BDL	-
26	Oil & Grease	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-
27	Dissolved Oxygen	mg/l	5.95	6.59	6.32	7.23	6.59	6.87	4

Sl. No	Parameters	Units	SW1	SW2	SW3	SW4	SW5	SW6	IS 2296: 1992
28	Total Kjeldahl Nitrogen	mg/l	7.49	BDL	BDL	BDL	BDL	BDL	-
29	Organic Phosphorus as P	mg/l	ND	ND	ND	ND	ND	ND	-
30	Total Coliform Count	MPN/100ml	1600	<2	8	900	22	TNTC	5000
31	E coli	MPN/100ml	34	<2	<2	170	<2	43	-

BDL – Below Detectable Limit, ND – Not Detected, TNTC - Too Numerous to Count, MDL – Minimum Detectable Limit *Source: Primary survey by EIA Study Team*

PO4, K and Oil & Grease : MDL-1 mg/l; Cu, Cr, Pb, Ni : MDL-0.01 mg/l; Cd : MDL- 0.001 mg/l

Table 14-23: Surface Water Quality of Study Area Cont...

Sl. No	Parameters	Units	SW7	SW8	SW9	SW10	SW11	SW12	IS 2296: 1992
1	pH value	--	7.92	7.14	7.21	6.85	6.89	6.50	6.0 – 9.0
2	Conductivity	µS/cm	350	28000	5300	20000	4100	15700	-
3	Total Suspended Solids	mg/l	8	BDL	6	9	6	8	-
4	Total Dissolved Solids	mg/l	262	18560	3361	13521	2715	10764	1500
5	Total Alkalinity as CaCO3	mg/l	82.95	59.25	35.55	59.25	23.7	47.4	-
6	Total Hardness as $CaCO_3$	mg/l	76	2800	380	1460	1360	1200	-

Sl. No	Parameters	Units	SW7	SW8	SW9	SW10	SW11	SW12	IS 2296: 1992
7	Calcium as Ca	mg/l	19.24	240.48	40.08	96.19	32.06	104.21	-
8	Magnesium as Mg	mg/l	6.80	534.6	68.04	296.46	68.04	228.42	-
9	Chloride as Cl	mg/l	30.86	9075.2	1315.90	7260.16	1134.4	5898.88	600
10	Sulphate as SO4	mg/l	14.47	421.26	129.49	279.89	96.82	217.06	400
11	Fluoride as F	mg/l	0.22	1.06	0.28	0.86	0.28	1.03	1.5
12	Iron as Fe	mg/l	1.57	0.23	0.32	0.54	0.40	0.37	0.5
13	Nitrate as NO3	mg/l	6.07	BDL	10.73	1.69	9.44	7.93	50
14	Phosphate as PO_4	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-
15	Sodium as Na	mg/l	24	1820	560	1880	460	1420	-
16	Potassium as K	mg/l	BDL	3	2	BDL	BDL	4	-
17	Copper as Cu	mg/l	BDL	BDL	0.04	BDL	0.02	0.06	1.5
18	Manganese as Mn	mg/l	BDL	BDL	BDL	0.25	BDL	BDL	-
19	Cadmium as Cd	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.01
20	Zinc as Zn	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	15

Sl. No	Parameters	Units	SW7	SW8	SW9	SW10	SW11	SW12	IS 2296: 1992
21	Chromium as Cr	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05
22	Lead as Pb	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.1
23	Nickel as Ni	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-
24	B O D (3 days at 27^{O} C)	mg/l	8.9	9.8	14.6	6.2	5.6	14.2	3
25	C O D	mg/l	190	190	114	124	89	210	-
26	Oil & Grease	mg/l	BDL	BDL	2.1	BDL	1.2	2.6	-
27	Dissolved Oxygen	mg/l	6.9	6.7	7	7.1	7.1	7.7	4
28	Total Kjeldahl Nitrogen	mg/l	2.6	4.3	6.3	3.6	4.3	3.6	-
29	Organic Phosphorus as P	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-
30	Total Coliform Count	MPN/100ml	Absent	50	50	Absent	Absent	70	5000
31	E coli	MPN/100 ml	Absent	Absent	Absent	Absent	Absent	Absent	-

BDL – Below Detectable Limit, ND – Not Detected, TNTC - Too Numerous to Count, MDL – Minimum Detectable Limit *Source: Primary survey by EIA Study Team*

PO4, K and Oil & Grease : MDL-1 mg/l; Cu, Cr, Pb, Ni : MDL-0.01 mg/l; Cd : MDL- 0.001 mg/l

14.4.1.12.3 Ground Water Quality Assessment

The stretch of Silver Line rail corridor will run through Thiruvananthapuram to Kasaragod via Districts Kollam, Pathanamthitta, Alappuzha, Kottayam, Ernakulam, Thrissur, Malappuram Kozhikode, and Kannur. WATER is one of the essential natural resources for sustaining life on the blue planet “Earth”. Keeping in view the importance of ground water to the local community, 12 representative ground water sampling locations along the proposed alignment were identified and analyzed for physico-chemical parameters and bacteriological parameters to establish the baseline status of the existing ground water in the project area. The description of ground water quality monitoring locations is presented in Table 14-24 and the ground water quality status (compared with Indian standards for drinking water quality IS 10500: 2012) are presented in Table 14-25 and Table 14-26. The overall groundwater quality conforms to the acceptable limit of drinking water standards (IS: 10500-2012) at most of the locations except Iron is exceeded the limit at four locations. Bacteriological contamination found at eight locations. The groundwater will be suitable for domestic and drinking purposes after proper treatment.

Table 14-24: Description of Ground Water Quality Monitoring Locations

Sl. No.	Location Code	Location	GPS Coordinates	Ground Water Source
1	GW1	Kochuveli, Thiruvananthapuram	N 8° 30’ 44.88” E 76° 53’ 52.43”	Open Well
2	GW2	Mukhathala, Kollam	N 8° 53’ 40.55” E 76° 39’ 27.09”	Open Well
3	GW3	Chengannur	N 9°20’ 19.873” E 76° 38’ 37.926”	Open Well
4	GW4	Kottayam	N 9° 34’ 39.821” E 76° 32’ 22.523”	Open Well
5	GW5	Ernakulam	N 10° 00’ 27.3” E 76° 22’ 42.4”	Open Well
6	GW6	Thrissur	N 10° 30’ 34.4” E 76° 12’ 20.6”	Open Well
7	GW7	Tirur	N 10^{0}55’42.9” E 75^{0}54’52.0”	Open Well

Sl. No.	Location Code	Location	GPS Coordinates	Ground Water Source
8	GW8	Kozhikode	N 11^{0}14'45.5" E 75^{0}46'49.4"	Open Well
9	GW9	Near to Badagra – Thiruvallur- Perumpa Rd	N 11^{0}35'22.2" E 75^{0}37'17.2"	Open Well
10	GW10	Kannur	N 11^{0}52'57.7" E 75^{0}21'47.3"	Open Well
11	GW11	Near Vadamkumkad Bus Stop	N 12^{0}09'13.3" E 75^{0}10'31.3"	Open Well
12	GW12	Kasaragod	N 12^{0}29'31.6" E 74^{0}59'11.3"	Open Well

Table 14-25: Ground Water Quality of Study Area

Sl. No.	Parameters	Units	GW1	GW2	GW3	GW4	GW5	GW6	Limit as Per IS: 10500:2012	
									Acceptable	Permissible
1	pH value	--	6.87	5.16	5.99	5.98	7.27	5.21	6.5 – 8.5	No Relaxation
2	Conductivity	µS/cm	580	113	99	135	486	134	-	-
3	Total Suspended Solids	mg/l	BDL	BDL	BDL	3.2	2.5	32	-	-
4	Total Dissolved Solids	mg/l	261	51	46	63	242	62	500	2000
5	Total Alkalinity as $CaCO_3$	mg/l	43.51	BDL	20.61	16.03	74.43	BDL	200	600
6	Total Hardness as $CaCO_3$	mg/l	110	04	24	24	95	18	200	600
7	Calcium as Ca	mg/l	39.2	1.6	5.6	5.6	28	4.8	75	200
8	Magnesium as Mg	mg/l	2.92	BDL	2.43	2.43	6.09	1.46	30	100
9	Chloride as Cl	mg/l	53.42	23.31	7.77	14.57	63.14	20.39	250	1000
10	Sulphate as SO_4	mg/l	88.59	BDL	10.43	9.77	34.35	4.92	200	400
11	Fluoride as F	mg/l	0.10	BDL	BDL	BDL	BDL	BDL	1.0	1.5

Sl. No.	Parameters	Units	GW1	GW2	GW3	GW4	GW5	GW6	Limit as Per IS: 10500:2012	
									Acceptable	Permissible
12	Iron as Fe	mg/l	0.10	0.09	BDL	1.49	0.35	0.09	0.3	No Relaxation
13	Nitrate as NO_3	mg/l	2.28	2.15	BDL	BDL	0.95	4.43	45	No Relaxation
14	Phosphate as PO_4	mg/l	BDL	0.68	0.83	BDL	0.20	BDL	-	-
15	Sodium as Na	mg/l	55.5	14.9	8.0	11.5	48.3	10.8	-	-
16	Potassium as K	mg/l	13.9	2.9	4.2	7.9	11.9	7.6	-	-
17	Copper as Cu	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05	1.5
18	Manganese as Mn	mg/l	0.029	0.028	0.118	0.121	0.057	0.056	0.1	0.3
19	Cadmium as Cd	mg/l	0.001	0.001	BDL	BDL	BDL	0.001	0.003	No Relaxation
20	Zinc as Zn	mg/l	0.032	0.119	0.020	0.032	0.104	0.091	5.0	15
21	Chromium as Cr	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05	No Relaxation
22	Lead as Pb	mg/l	BDL	BDL	BDL	BDL	0.010	BDL	0.01	No Relaxation
23	Nickel as Ni	mg/l	BDL	0.010	BDL	BDL	BDL	BDL	0.02	No Relaxation

Sl. No.	Parameters	Units	GW1	GW2	GW3	GW4	GW5	GW6	Limit as Per IS: 10500:2012	
									Acceptable	Permissible
24	B O D (3 days at 27^{O} C)	mg/l	3.6	BDL	BDL	BDL	BDL	BDL	-	-
25	C O D	mg/l	12	BDL	BDL	BDL	BDL	BDL	-	-
26	Oil & Grease	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
27	Dissolved Oxygen	mg/l	6.22	6.5	6.96	6.96	7.1	6.96	-	-
28	Total Kjeldahl Nitrogen	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
29	Organic Phosphorus as P	mg/l	BDL	ND	ND	ND	ND	ND	-	-
30	Total Coliform Count	MPN/100ml	34	50	500	30	500	70	Absent	No Relaxation
31	E coli	MPN/100ml	22	02	11	<2	02	<2	Absent	No Relaxation

BDL – Below Detectable Limit.

Source: Primary survey by EIA Study Team

Table 14-26: Ground Water Quality of Study Area Cont…

Sl. No	Parameters	Units	GW7	GW8	GW9	GW10	GW11	GW12	Limit as per IS: 10500:2012	
									Acceptable	Permissible
1	pH value	--	7.78	7.54	7.07	6.99	6.80	6.17	6.5 – 8.5	No Relaxation
2	Conductivity	µS/cm	290	390	43	210	220	160	-	-
3	Total Suspended Solids	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
4	Total Dissolved Solids	mg/l	188.5	253.5	27.95	136.5	143	104	500	2000
5	Total Alkalinity as CaCO3	mg/l	14.22	109.02	9.48	28.44	47.4	28.44	200	600
6	Total Hardness as $CaCO_3$	mg/l	56	112	10	32	44	24	200	600
7	Calcium as Ca	mg/l	17.64	43.29	2.40	12.02	15.23	8.02	75	200
8	Magnesium as Mg	mg/l	2.92	BDL	BDL	BDL	1.46	BDL	30	100
9	Chloride as Cl	mg/l	30.86	19.97	9.98	24.50	20.87	22.69	250	1000
10	Sulphate as SO4	mg/l	19.08	10.80	3.91	5.29	7.43	5.42	200	400
11	Fluoride as F	mg/l	BDL	0.14	BDL	BDL	BDL	BDL	1.0	1.5
12	Iron as Fe	mg/l	0.07	0.38	BDL	0.05	0.54	0.10	0.3	No Relaxation

Sl. No	Parameters	Units	GW7	GW8	GW9	GW10	GW11	GW12	Limit as per IS: 10500:2012	
									Acceptable	Permissible
13	Nitrate as NO_3	mg/l	13.17	10.80	BDL	6.21	4.99	3.70	45	No Relaxation
14	Phosphate as PO_4	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
15	Sodium as Na	mg/l	18	12	03	21	10	19	-	-
16	Potassium as K	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
17	Copper as Cu	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05	1.5
18	Manganese as Mn	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.1	0.3
19	Cadmium as Cd	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.003	No Relaxation
20	Zinc as Zn	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	5	15
21	Chromium as Cr	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.05	No Relaxation
22	Lead as Pb	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.01	No Relaxation
23	Nickel as Ni	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.02	No Relaxation
24	B O D (3 days at 27^{O} C)	mg/l	BDL	BDL	BDL	1.33	BDL	1.9	-	-

Sl. No	Parameters	Units	GW7	GW8	GW9	GW10	GW11	GW12	Limit as per IS: 10500:2012	
									Acceptable	Permissible
25	C O D	mg/l	14	10	08	24	14	18	-	-
26	Oil & Grease	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
27	Dissolved Oxygen	mg/l	7.4	6.9	7.2	6.9	6.8	7.1	-	-
28	Total Kjeldahl Nitrogen	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
29	Organic Phosphorus as P	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	-	-
30	Total Coliform Count	MPN/100ml	Absent	Absent	Absent	30	Absent	40	Absent	No Relaxation
31	E coli	MPN/100ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	No Relaxation

BDL – Below Detectable Limit.

Source: Primary survey by EIA Study Team

14.4.1.13 Land Environment

14.4.1.13.1 Land Use Pattern

Land use pattern of Kerala reveals that out of a total geographical area of 38.86 lakh hectare is classified according to thirteen different uses of land as given in Table and Figure. The cultivated area of the state comes to around 66.6% of the total geographical area. Within this, the Net Sown Area accounts for 52% and 16.83% of the cultivated area is sown more than once. Area under forest cover consist 28% and 11.37% of the area is put to non- agricultural use. Land Use Pattern in Kerala (2017 – 18) is shown in Table 14-27 and Figure 14-5.

Table 14-27: Land Use Pattern in Kerala 2017 – 18

S. No.	Classification of Land	Area (Hectare)	Percentage of Geographical areas
1	Forest	1081509	27.829
2	Land put to non-agricultural uses	443041	11.400
3	Barren and uncultivated land	10894	0.280
4	Permanent Pastures and Grazing land	0	0
5	Land under miscellaneous tree crops	2245	0.058
6	Cultivable waste	96491	2.483
7	Fallow other than current Fallow	49461	1.273
8	Current Fallow	57522	1.480
9	Marshy Land	14	0
10	Still Water	98889	2.545
11	Water Logged Area	3235	0.083
12	Social Forestry	2571	0.066
13	Net Area Sown	2040415	52.503
Total		**3886287**	**100**

Source: Department of Economics and Statistics, Kerala

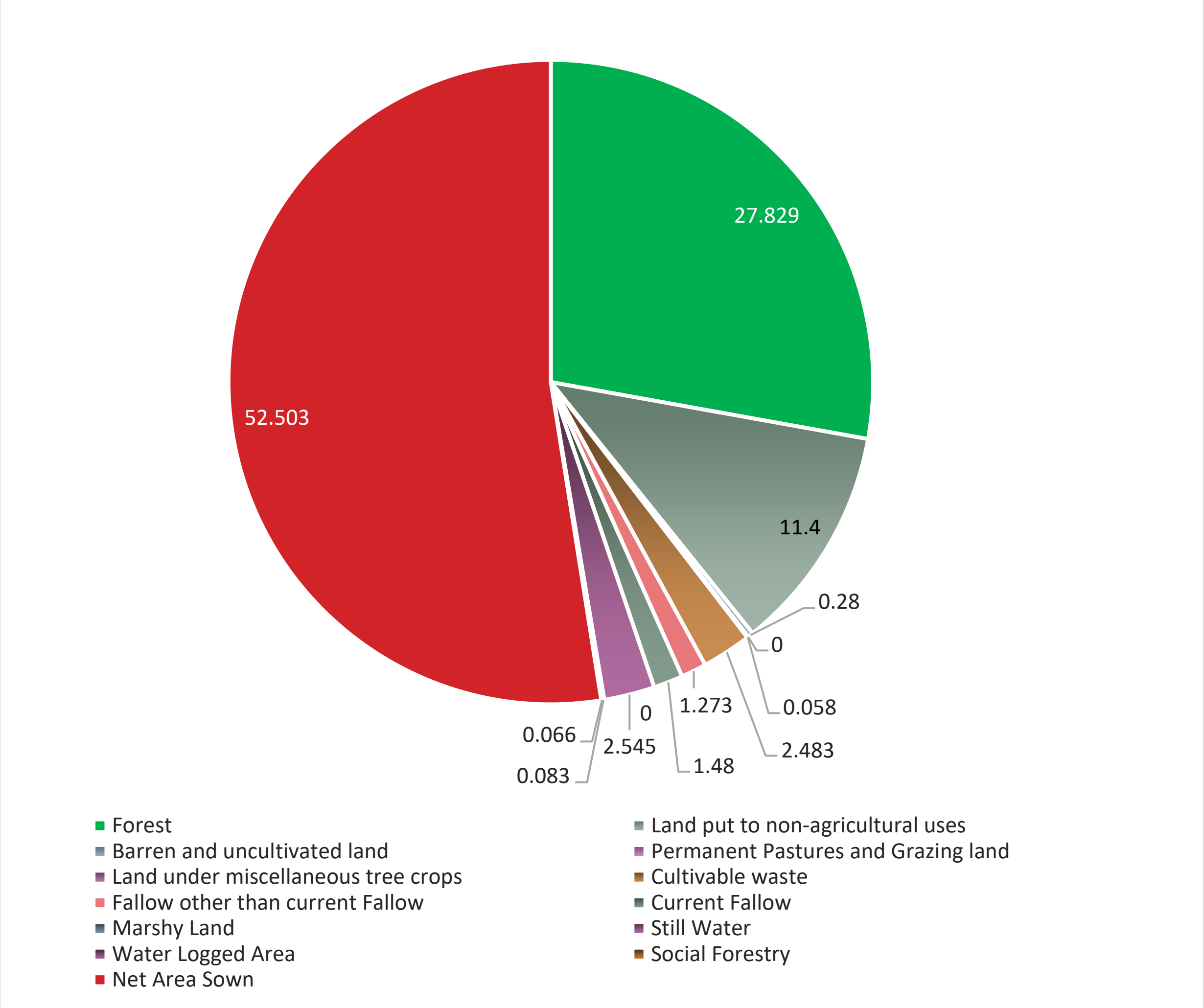


Figure 14-5: Land Use Pattern of Kerala

14.4.1.13.2 Soil Quality

In general, the soils of Kerala are acidic, kaolintic and gravelly with low CEC (Cation Exchange Capacity), low water holding capacity and high phosphate fixing capacity. Climate topography, vegetation and hydrological conditions are the dominant factors of soil formation. Based on the morphological features and physico-chemical properties, the soils of the State have been classified into red loam, laterite coastal alluvium, riverine alluvium, Onattukara alluvium, brown hydromorphic, saline hydromorphic, Kuttanad alluvium, black soil and forest loam. To know the existing soil characteristics of the study area, soil samples were collected from 16 locations including stations and depots location along the Silver Line rail corridor. The soil quality analysis results shows that soils are very strongly acidic to neutral in nature. The description of Soil quality monitoring locations and physicochemical characteristics of soil are presented in Table 14-28, Table 14-29 and 14-30 respectively.

Table 14-28: Description of Soil Quality Monitoring Locations

Sl. No.	Location Code	Location	GPS Coordinates
1	S1	Kochuveli, Proposed Railway Station	8° 30’ 44.88” N 76° 53’ 52.43” E
2	S2	Thottakkad (Near NH)	8° 44’ 26.26” N 76° 48’ 25.77” E
3	S3	Kollam, Mukhathala, Proposed Railway Station	N 8° 53’ 40.55” E 76° 39’ 27.09”
4	S4	Chengannur Railway Station	N 9° 20’ 19.873” E 76° 38’ 37.926”
5	S5	Muttampalam, Kottayam, Proposed Railway Station	N 9° 34’ 39.821” E 76° 32’ 22.523”
6	S6	Near Info park, Ernakulam Proposed Railway Station	N 10° 0’ 31.564” E 76° 22’ 38.743”
7	S7	Thrissur Railway Station	N 10° 30' 32.1336" E 76° 12' 23.9472"
8	S8	Tirur Railway Station	N 10° 55' 42.9384" E 75° 54' 51.9696"
9	S9	Near Tirur Ponnani Road	N 10° 32' 5.046" E 76° 12' 54.2052"
10	S10	Kozhikode Railway Station	N 11° 14' 45.528" E 75° 46' 49.4436"
11	S11	Near Purakkad - Muchukunnu Road	N 11° 29' 51.81" E 75° 38' 35.1348"
12	S12	Near Chathamangalarn	N 11° 36' 59.2884" E 75° 35' 52.2492"
13	S13	Kannur Railway Station	N 11° 53' 3.4296" E 75° 22' 5.3616"
14	S14	Near Nambrikal Dam	N 12° 16' 7.5864" E 75° 6' 59.2416"
15	S15	Kasaragod Railway Station	N 12° 29' 31.5636" E 74° 59' 11.3244"
16	S16	Kasaragod Depot	N 12° 30' 29.484" E 74° 58' 33.5856"

Table 14-29: Soil Quality of Study Area

Sl. No	Parameters	Units	S1	S2	S3	S4	S5	S6	S7	S8
1	Colour	--	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown	Reddish Brown	Black Brown
2	pH value	--	6.36	5.16	4.77	5.58	4.91	5.50	5.65	6.51
3	Conductivity	mS/cm	0.027	0.061	0.019	0.048	0.045	0.105	0.015	0.05
4	Moisture Content	%	80.09	79.58	79.09	79.28	78.76	79.08	14.06	12.8
5	Sand	%	69.12	69.27	63.39	63.44	63.36	63.62	73	80
6	Silt	%	0.11	0.03	0.03	0.01	0.02	0.06	19	16
7	Clay	%	30.77	30.7	36.58	36.55	36.62	36.32	08	04
8	Porosity	%	51.76	57.31	58.94	52.54	54.56	50.98	14.1	21.3
9	Bulk density	gm/cm^3	1.401	1.068	1.084	1.120	1.201	1.0	1.430	1.463
10	Water Holding Capacity (WHC)	%	46.34	44.32	47.17	47.17	45.24	43.13	32.12	36.5
11	Organic Matter	%	5.52	9.45	7.79	6.56	6.61	5.12	3.6	4.48
12	Organic Carbon	%	3.20	5.48	4.52	3.80	3.83	2.97	2.1	2.6
13	Iron as Fe	mg/kg	10.99	9.73	8.25	11.17	10.24	9.64	1.32	0.74

Sl. No	Parameters	Units	S1	S2	S3	S4	S5	S6	S7	S8
14	Zinc as Zn	mg/kg	BDL	BDL	BDL	BDL	BDL	BDL	1.83	2.32
15	Copper as Cu	mg/kg	22.48	33.17	18.37	23.89	38	23.20	15.4	7.8
16	Bicarbonate	mg/kg	ND	ND	ND	ND	ND	ND	10.2	13.6
17	Calcium as Ca	mg/kg	34.76	64.41	69.31	31.47	75.59	76.11	580	412
18	Magnesium as Mg	mg/kg	42.32	39.21	42.19	38.32	22.40	46.33	321	89.6
19	Chloride as Cl	mg/kg	424.52	442.57	449.17	237.47	189.67	201.86	19.6	13.93
20	Sodium as Na	mg/kg	21.72	35.43	20.93	18.09	21.44	17.43	207	68
21	Orthophosphate	mg/kg	ND	ND	ND	ND	ND	ND	248	187
22	Sulphate	mg/kg	4.2	3.4	4.6	3.1	3.0	5.2	236	198
23	Available Nitrogen as N	%	0.07	0.04	0.09	0.13	0.1	0.04	0.07	0.12
24	Available Phosphorus as P	%	ND	ND	ND	ND	ND	ND	0.08	0.05
25	Potassium as K	mg/kg	75.59	83.73	79.12	74.75	93.84	67.21	60	32.6
26	Cation Exchange Capacity (CEC)	meq/100g	6.27	5.79	6.32	5.93	6.16	6.10	16.7	19.4

ND: Not Detected, BDL: Below Detectable Limit

Source: Primary survey by EIA Study Team

Table 14-30: Soil Quality of Study Area Cont..

Sl. No	Parameters	Units	S9	S10	S11	S12	S13	S14	S15	S16
1	Colour	--	Light Brown	Red	Dark Brown	Dark Brown	Light Red	Light Brown	Reddish Brown	Brown
2	pH value	--	6.51	6.23	5.87	6.03	6.81	5.14	6.05	6.21
3	Conductivity	mS/cm	0.029	0.03	0.13	0.04	0.04	0.023	0.04	0.027
4	Moisture Content	%	8.56	15.2	26.44	20.5	21.7	17.73	21.4	13.6
5	Sand	%	74	50	42	68	80	78	81	76
6	Silt	%	20	26	30	22	18	20	11	22
7	Clay	%	06	02	28	10	02	02	08	02
8	Porosity	%	15.7	9.8	18.4	9.8	8.6	11.7	12.7	13.7
9	Bulk density	gm/cm^3	1.478	1.452	1.430	1.435	1.423	1.427	1.432	1.416
10	Water Holding Capacity (WHC)	%	9.7	46.3	12.85	47.2	46.3	47.1	38.5	41.9
11	Organic Matter	%	5.32	1.08	5.01	0.93	0.99	0.49	1.49	2.46
12	Organic Carbon	%	3.09	0.63	2.91	0.54	0.58	0.29	0.87	1.43
13	Iron as Fe	mg/kg	0.61	0.36	0.33	0.78	0.46	0.23	0.94	0.74

Sl. No	Parameters	Units	S9	S10	S11	S12	S13	S14	S15	S16
14	Zinc as Zn	mg/kg	3.45	1.63	ND	2.6	1.63	0.65	ND	ND
15	Copper as Cu	mg/kg	ND	ND	18.9	12.0	ND	10.5	26.0	8.5
16	Bicarbonate	mg/kg	4.1	9.1	3.6	6.3	13.6	5.8	9.7	3.2
17	Calcium as Ca	mg/kg	783	367	535	369	326	483	312	632
18	Magnesium as Mg	mg/kg	118	58.5	43.29	89.6	95.6	97	21	251
19	Chloride as Cl	mg/kg	29.8	18.57	24.7	23.1	17.5	32.6	36.2	21.7
20	Sodium as Na	mg/kg	167.8	63.5	80.97	62.3	65.4	56.9	63.7	85
21	Orthophosphate	mg/kg	243.3	174.9	209	214	165	137	210	243
22	Sulphate	mg/kg	294	165	249	203	326	187	176	210
23	Available Nitrogen as N	%	0.07	0.08	0.05	0.06	0.13	0.07	0.09	0.13
24	Available Phosphorus as P	%	0.07	0.04	0.068	0.04	0.08	0.04	0.05	0.07
25	Potassium as K	mg/kg	49.3	34.5	26.99	32.4	28.9	8.12	32.6	10.3
26	Cation Exchange Capacity (CEC)	meq/100g	19.7	17.8	15.4	16.5	16.3	18.7	10.6	13.7

ND: Not Detected, BDL: Below Detectable Limit

Source: Primary survey by EIA Study Team

14.4.1.14 Biological Environment: Ecology and Biodiversity

A preliminary field survey was carried out in November 2019 to provide detailed profile and baseline of the biological environment parallel to the proposed alignment. The identification of flora/fauna parallel to the corridor site and surrounding was done with personal observations along with review of secondary data.

Kerala with only 1.2% of India‘s landmass harbors 25.69% of flowering plant species and 26.59% of Pteridophytes recorded in India. Vertebrate diversity of Kerala is represented by 1,847 species in 330 families and 81 orders with Fishes (freshwater and marine) the most diverse group of vertebrates (905 species), followed by birds (500 species), reptiles (173 species), amphibians (151 species) and mammals (118 species).Out of 779 marine species, 93% is not included in any Schedules of Wildlife Protection Act. The highest level of endemism (between 77-102 species per sub basin) and highest species richness (133-160 species per sub basin) is found in the west flowing rivers namely Chaliyar, Bharatapuzha, Chalakkudy, Periyar, and Pamba with point endemics in certain cases.

14.4.1.14.1 Ecologically Sensitive Areas

The proposed Silver Line rail corridor is not a nationally or Internationally recognized area for nature or conservation. However, the Kerala State is known for its conservation and there are 17 Wildlife Sanctuaries (includes 2 Tiger Reserves, 2 Bird Sanctuaries, 1 Peafowl Sanctuary), 6 National Parks, 2 Biosphere Reserves and 1 Community Reserve in the state. The alignment lay out has been very wise as it doesn`t covers any protected areas like National Parks, Wildlife Sanctuary and Biosphere Reserves as per Wildlife Protection Act, 1972 along the both side of the alignment (10 km wider) of the proposed site or proposed station areas. No area or village along the alignment or proposed station falls under Western Ghats Notification, 2015. Hence, no ecologically sensitive areas were observed during our field survey and as per our secondary data review as per Kasturirangan and Gadgil Report on WGEEP. The proposed Silver Line rail activity is far away from such ecologically sensitive areas.

14.4.2 Socio-Economic Environment

The proposed planned development of Silver Line rail corridor has expected the rapid future growth of the area, subsequently will reduce road traffic and traffic congestions. The proposed rail corridor shall reduce the traffic in addition to contribution in managing better city life. The proposed rail corridor construction and operation needs to be studied from social environment perspectives.

14.4.2.1 Demographic Profile

Demography is one of the important indicators of environmental health of an area. It includes population, sex ratio, number of households, literacy, population density, etc.

The socio-economic data used in the section are derived from various sources, including the published data of Census of India, District Census Handbook, electronic media and published reports/journals.

Kerala consists of 14 districts spread over an area of 38863 sq. km. As per the census records 2011, the total population was 33,406,061. Out of this 48% were men and 52% were women. The decadal growth rate of Kerala's population is estimated at 4.9%. The sex ratio (females per 1000 males) of Kerala is 1084 and population density is 860 persons/sq. km. The distribution of population, demographic profile and employment pattern of Kerala is outlined in Table 14-31.

Table 14-31: Population, Demographic Profile and Occupational Pattern of Kerala

S. No.	Description	Units	Number
1	Geographical Area		
	Total	Sq. km.	38,863
	Rural	Sq. km.	31264
	Urban	Sq. km.	7599
2	Districts	No.	14
3	Taluks	No.	75
4	Villages	No.	1664
5	Towns	No.	520
6	Density		
	Total	Per sq. km.	860
	Rural	Per sq. km.	559
	Urban	Per sq. km.	2097
7	**Household**		
	Total	No.	7853754
	Rural	No.	4149641
	Urban	No.	3704113

S. No.	Description	Units	Number	
8	**Population**	**Total**	**Male**	**Female**
	Total	33406061	16027412	17378649
	Rural	17471135	8408054	9063081
	Urban	15934926	7619358	8315568
9	**(0-6) Child Population**			
	Total	3472955	1768244	1704711
	Rural	1823664	927888	895776
	Urban	1649291	840356	808935
10	**SC Population**			
	Total	3039573	1477808	1561765
	Rural	1818281	883819	934462
	Urban	1221292	593989	627303
11	**ST Population**			
	Total	484839	238203	246636
	Rural	433092	213208	219884
	Urban	51747	24995	26752
12	**Literate**			
	Total	28135824	13704903	14430921
	Rural	14549320	7132430	7416890
	Urban	13586504	6572473	7014031
13	**Illiterate**			
	Total	5270237	2322509	2947728

S. No.	Description	Units		Number
	Rural	2921815	1275624	1646191
	Urban	2348422	1046885	1301537
	Status	**Total**	**Rural**	**Urban**
14	Family Size	4.25	4.21	4.30
15	Sex Ratio	1084	1078	1091
16	Total SC Population	9.10%	10.41%	7.66%
17	Total ST Population	1.45%	2.48%	0.68%
18	**Workers Pattern**	**Total**	**Male**	**Female**
	Total	11619063	8451569	3167494
	Rural	6341957	4507501	1834456
	Urban	5277106	3944068	1333038
19	**Type of Workers**	**Main**	**Marginal**	**Non**
	Total	9329747	2289316	21786998
	Rural	4930191	1411766	11129178
	Urban	4399556	877550	10657820
20	**Employment Pattern**	**Total**	**Rural**	**Urban**
	Cultivators	544932	481651	63281
	Agriculture	919136	760632	158504
	Industrials Household	198281	104642	93639
	Others	7667398	3583266	4084132

Source: Census of India 2011

14.4.2.2 Major Socio – Economic Activities

14.4.2.2.1 Industries (SSIs/MSMEs)

As on September 17, 2015, the total number of working SSIs/MSMEs registered in Kerala are 2,57,466. Out of the total SSIs/MSMEs, 3.84% were promoted by SC entrepreneurs, 0.72% by STs and 24.97% by women entrepreneurs. The total investment was 17,98,646.38 lakhs while the total value of goods and services produced was 67,65,143.93 lakhs and the total number of employments generated was 13,18,666 numbers.

14.4.2.2.2 Marine Fishing

The total fish production in Kerala in 2017-18 was 6.73 lakh tonnes, of which Marine fish landings were 4.84 lakh tonnes and Inland fish production was 1.89 lakh tonnes. As per records of Directorate of Fisheries, Government of Kerala, during 2014-15, marine fish landing in Kerala was 524000 tons, which comprised of more than 80 types of fishes. The most prominent species were oil sardine (27%), Indian mackerels (9.0%), non-penaeid prawns (6.9%) and scads (6.6%). The other prominent species were stolephorus, cuttlefish, ribbon fishes, thereadfin breams. Marine fish production has decreased from 5.24 lakh tonnes in 2014-15 to 5.17 lakh tonnes in 2015-16.

14.4.2.2.3 Inland Fishing

Besides, 44 perennial rivers, there are large number of water bodies in Kerala, which act as fishing ground for local people. During 2015-16, the share of inland fish production in the total fish production of the state was 29%. Kerala has not utilized its potential in Inland fishing. Kerala has over 7% of the water bodies in the country, but its share in Inland fishing is lower than that of many other states.

14.4.2.2.4 Agriculture

Kerala has unique and diverse agro-climatic specialities, which enable it to cultivate many types of crops. As per 2011 Census, about 9.2 lakh persons (males, 82.8% and 17.2% females) were engaged in agriculture activities. There has been a gradual shift from the food crops to cash crops and at present the cropping pattern in Kerala is dominated by cash crops. Food crops comprising rice, tapioca and pulses accounted for just 10.12 per cent of the total cropped area in 2017-18 while cash crops (cashew, rubber, pepper, coconut, cardamom, tea and coffee) constituted 61.6%. Coconut occupies the largest area with 29.5% coverage followed by rubber with 21.4%. Rice comes third with 7.3% of the total cropped area. Except for rice, pulses, banana, turmeric, tapioca and rubber, all other crops recorded a declining trend in area under cultivation. Trend in Area, Production and Productivity of Principal Crops of Kerala are presented in Table 14-32.

Table 14-32: Area, Production and Productivity of Principal Crops of Kerala

Sl. No.	Crops	Area (Ha)		Production (T)		Productivity (Kg/Ha)	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
1	Rice	171398	189086	436483	521310	2547	2757
2	Pulses	1738	1992	1711	2045	984	1027
3	Pepper	85207	85141	34065	37955	400	446
4	Ginger	5151	4370	20478	18978	3976	4343
5	Turmeric	2632	2777	6506	8822	2472	3177
6	Cardamom	39080	39080	17147	18350	439	470
7	Arecanut	97696	94580	116839	108516	1196	1147
8	Banana	57158	62106	489322	565829	8561	9111
9	Other Plantations	57140	54455	395806	379683	6927	6972
10	Cashew	41661	39720	27944	25629	671	645
11	Tapioca	68664	70193	2529729	2697319	36842	38427
12	*Coconut	781496	760443	5384	5230	6889	6878
13	[1]Coffee	84976	84976	63476	66465	747	782
14	[2]Tea	30205	30205	61505	62230	2036	2060
15	[3]Rubber	551050	551115	540400	540775	981	981

**Production in Million Nuts*

Source: Directorate of Economics & Statistics, Kerala;[1]Coffe Board, [2]Tea Board, [3]Rubber Board

14.4.2.2.5 Tourism

Tourism is a social, cultural and economic phenomenon related to the movement of people to places outside their usual place of residence, pleasure being the usual motivation. With increasing globalization and disposable income, tourism has over the last few decades become one of the largest and fastest growing industries.

International and regional tourism contributes to economic growth, job creation and development in nations all around the world.

Kerala, God's own country, an internationally recognized popular tourist destination, is known for its tourists' attractions, namely very long coastal line, lakes, backwaters, beaches as well tea gardens on hills and number of archaeological monuments and museums. Over 16.7 million tourists visited Kerala in 2018 as against 15.76 million the previous year, recording an increase of 5.94%. Of the total footfalls, 1.09 million were foreign tourists (Table 28). The share of revenue from foreign visitors touched Rs 8,764.46 crore. Domestic tourism sector also gained during the period with visitors exceeding 15.6 million, showing an increase of 6.35 per cent. The Trend in domestic and foreign tourist arrivals to Kerala during the year 2008 – 18 are presented in Table 14-33.

Table 14-33: Trends in Domestic & Foreign Tourist Arrivals during the year 2008 – 18

Year	Domestic Tourist	% Increase	Foreign Tourist	% Increase	Total Tourist	% Increase
2008	7591250	14.28	598929	16.11	8190179	14.41
2009	7913537	4.25	557258	– 6.96	8470795	3.43
2010	8595075	8.61	659265	18.31	9254340	9.25
2011	9381455	9.15	732985	11.18	10114440	9.29
2012	10076854	7.41	793696	8.28	10870550	7.48
2013	10857811	7.75	858143	8.12	11715954	7.78
2014	11695411	7.71	923366	7.60	12618777	7.71
2015	12465571	6.59	977479	5.86	13443050	6.53
2016	13172535	5.67	1038419	6.23	14210954	5.71
2017	14673520	11.39	1091870	5.15	15765390	10.94
2018	15604661	6.35	1096407	0.42	16701068	5.94

Source: Ministry of Statistics, GoI & Department of Tourism, Kerala

14.4.2.3 Health Infrastructure & Diseases

Kerala has good health care facilities, and its Ayurvedic treatment centres are well known in the World and one of the major tourists' attractions. As on March 31,2013, there were in total 1281 Govt. Allopathic Institutions, 19 speciality hospitals and 49 other institutions. The Govt. Allopathic Institutions include 233 Community Health Centres, 682 Primary Health Centres (PHCs), 173 round the clock PHCs. Diarrhoea is the most common disease of Kerala. Other communicable diseases are Hepatitis A & Hepatitis B, dengue fever, malaria, typhoid, leptospirosis, scrub typus and chikungunya.

14.4.2.4 Historical / Archaeological Importance

14.4.2.4.1 Archaeological Locations in the Study Area

Kerala has number of important archaeological and museums , which are attraction to large number of domestic and foreign tourists. There are no historical / archaeological monuments within the 300 m distance of Silver Line corridor.

The Ancient Monument and Archaeological Sites and Remains (Amendments and Validation) Act, 2010 specifies the prohibited area of 100 m from site whereas regulated area is 200 m from the limit of prohibited area. No construction is allowed in prohibited area while construction can be taken up in regulated area after getting the approval from the Archaeological Survey of India (ASI).

List of archaeological monuments under jurisdiction of Archaeological Survey of India, Thrissur, Kerala is presented in Table 14-34.

Table 14-34: List of Archaeological Monuments of Kerala

Sl. No.	Name of the Monument	Locality	District
1	Tellicherry Fort	Tellicherry	Kannur
2	Bekal Fort	Pallicherry	Kasaragod
3	Remains of Fort	Thangassery	Kollam
4	Palghat Fort	Yakkaradesam	Palakkad
5	Anjengo Fort	Anjengo	Thiruvananthapuram
6	Jain Temple	Sultan battery (Kidanganadu)	Wayanad
7	St. Francis Church	Cochin	Ernakulam
8	Fort St. Angelo	Cannanore	Kannur
9	Mural Paintings (16th-17th Century) on the walls of the Mattancherry Palace	Mattancherry Town	Ernakulam
10	Ariyyanur Umbrellas. A prehistoric site consisting of seven or more Kuldakala or umbrella monuments.	Ariyyanur	Thrissur
11	Kudakkallu Parambu, A prehistoric site consisting of 50 to 60 Kudakala or umbrella monuments.	Cheramanagad	Thrissur
12	Burial Cave of Chovannur	Chovannur	Thrissur
13	Burial Cave of Eyyal	Eyyal	Thrissur
14	Twenty nine wooden bracket images on the outer walls of Srikoil of the Vishnu Temple at Katavallur and other works of art in the same shrine.	Katavallur	Thrissur

Sl. No.	Name of the Monument	Locality	District
15	Burial Cave of Kakkad	Kunnamkulam	Thrissur
16	Burial Cave of Kattakampal	Kattakampal	Thrissur
17	Burial Cave of Kandanasseri	Kandanasseri	Thrissur
18	Shiva Temple ,Tiruvanchikulam	Tiruvanchikulam	Thrissur
19	Mural Paintings on the walls of the Sri Rama Swami Temple at Triprayar	Triprayar	Thrissur
20	Mural Paintings (16th-17t Century) on the walls of the Thenkailasanatha Temple	Trichur	Thrissur
21	Temples of Parasurama, Brahma, Siva and Matsya together	Tiruvallam	Thiruvananthapuram
22	Rock cut cave Vizhinjam	Vizhinjam	Thiruvananthapuram
23	Siva Temple at Netirimanagalam, Pattambi	Pattambi	Palakkad
24	Siva Temple, Peruvanam	Cherpu	Thrissur
25	Siva Temple, Chemmanthitta	Chemmanthitta Thalappilly	Thrissur
26	Siva Temple, Pallimanna	Vadakkanchery	Thrissur
27	Siva Temple, Avittathur	Kuduppasery	Thrissur
28	Vishnu Temple,Vishnugudi	Nadavayal	Wayanad
29	Janardhana Temple	Panamaram	Wayanad

Source: Archaeological Survey of India, Thrissur, Kerala

14.4.2.4.2 World Heritage Site

The mountain chain of the Western Ghats represents geomorphic features of immense importance with unique biophysical and ecological processes has been included in the list of World Heritage sites by UNESCO. The areas of Western Ghats included in the World Heritage Site are presented in Table 14-35.

Table 14-35: Areas of Western Ghats included in the World Heritage Site

Sl. No.	Sub Cluster Names	PA's/ RF/ Range/ Forest Division
1	Agasthyamalai	Shendurney Wildlife Sanctuary Neyyar Wildlife Sanctuary Peppara Wildlife Sanctuary Kulathupuzha Range Palode Range
2	Periyar	Periyar Tiger Reserve Ranni Forest Division Konni Forest Division Achencovil Forest Division
3	Anamalai	Eravikulam National Park Mankulam Division Chinnar Wildlife Sanctuary Mannavan Shola Karianshola

Sl. No.	Sub Cluster Names	PA's/ RF/ Range/ Forest Division
4	Nilgiri	Silent Valley National Park New Amarambalam Reserve Forests Kalikavu Range Attappady Reserve Forest
5	Thalakkavery	Aralam Wildlife Sanctuary

Source: Kerala Forest Department

The site also has an exceptionally high level of biological diversity and endemism. It is recognized as one of the world's eight "hottest hotspots" of biological diversity. The forests of the site include some of the best representatives of non-equatorial tropical evergreen forests anywhere and are home to at least 325 globally threatened flora, fauna, bird, amphibian, reptile and fish species.

14.4.2.5 Traffic Survey

Traffic Study and Ridership estimations are the main component which implies finalizing a feasible alignment plan of the proposed Silver Line Rail Corridor. The results of traffic analysis will form inputs for assessing the traffic diversion to the proposed corridor, generated and development traffic. The forecast of the traffic helps in planning and designing of the stations, rolling stock, train operation plan, estimates of revenue collection, benefits of Silver Line and many other services. Summary of daily ridership and Peak Hour Per Directional Trip (PHPDT) for Silver Line rail between Thiruvananthapuram and Kasaragod for horizon years 2025 – 26, 2029 – 30, 2041 – 42 and 2052 – 53 are presented in Table 14-36.

Table 14-36: Summary of daily ridership and Peak Hour Per Directional Trip

Horizon Year	Daily Ridership	Peak Hour Per Directional Trip (PHPDT)
2025 – 26	79,934	1,440
2029 – 30	94,672	1,780
2041 – 42	132,944	2,640
2052 – 53	158,946	3,160

14.5 ANTICIPATED ENVIRONMENTAL & SOCIAL IMPACTS AND MITIGATION MEASURES

An environmental and social impact is defined as any change to an existing condition of the environment. The activities of the Project have the potential to impact the environment, society and economy in both positive and negative ways, and these were identified and assessed in this Chapter. This chapter assesses the nature, type and magnitude of the potential impacts likely on the various relevant physical, biological and cultural environmental components along the project corridor and its suitable mitigation. For the assessment of impacts, the baseline information based on the field visits and the primary surveys of the various environmental components carried out. The description of the impacts on the individual components has been structured as per the discussion in Sub Chapter 14.4 Baseline Environmental Quality & Socio-Economic Status of this report.

The impacts on the various environmental components were assessed considering following stages of the project planning and implementation:

- Planning phase;
- Construction phase; and
- Operation phase

The description and magnitude of impacts for the various environmental components as visualised for the project are presented in the following sections along with proposed mitigation.

14.5.1 Identification of Environmental Impacts

The environmental impact assessment process begins by identifying the development and operational activities resulting from the proposed project. For the environmental impact study, 500 m on either side of the proposed centre line of the Silver Line project has been considered as the Zone of Influence. For most of the issues involving physical impacts, the study area could be considered as the project “footprint,” or the area that would be directly used for the proposed Silver Line alignment and associated project facilities like construction yard, stations, maintenance depots, tunnel inspection shafts, power sub-stations, various locations proposed for traction power facilities and power connections, etc.

Potential impacts due to the proposed Silver Line rail project on the various sectors of environment in different phases of the project cycle namely pre-construction, construction and operation phase have been identified and presented in Table 14-37.

Table 14-37: Environmental Impact Matrix

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
A: Pre-Construction and Construction Phase			
Natural Environment			
1	Topography and Geology	Embankments, cuttings, viaduct/bridges structure and tunnel excavation may lead to changes in the topography of the area.	Permanent

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
		The expected impact on topography and geographical features is negligible or small	
2	Hydrology	Construction works along the river/channel would affect hydrological situation in such channel/river. Ground water hydrology impact due to creation of tunnel and compacted base in underground portion.	Permanent
3	Local Meteorological Condition	Temporary adverse impact due to cutting of Trees and vegetation from RoW, stations and depot sites.	Temporary
4	Protected Areas /Sanctuaries	Negligible impact, no such area is getting directly affected.	Permanent
5	Ecosystem	Existing trees and plants on the RoW and work sites would be removed tentatively or permanently for construction	Temporary/ Permanent
6	Landscape	Construction works would affect the landscape in the project site.	Permanent
Pollution Control			
7	Air Environment	Emission of exhaust gases from construction equipment and vehicles and fugitive dust emission due to construction works will cause air pollution in and around the construction sites.	Temporary
8	Noise & Vibration	Noise and vibration caused by operation of construction vehicles/equipment could annoy the residents and school/hospital nearby. Vibration caused by such construction works may damage the houses and other kinds of building structures such as cracks in the wall/foundation of old buildings /structures.	Temporary

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
9	Water Environment	Muddy water from construction sites and oil spill from construction equipment and vehicles could cause water pollution in the channel/river in and around the construction sites.	Temporary
10	Land Environment	Construction works along the river/channel sections could cause soil erosion. in case of leakage of lube oil/HSD from the construction yard can lead to deterioration of soil quality/loss of productive soil.	Temporary
11	Bottom Sediment	There may be some disturbance to the bottom sediments during the construction of viaduct/bridges.	Temporary
12	Global Warming	Cutting of existing trees and plants alongside the RoW of the railway will reduce CO_2 sequestration. However, since trees will be replanted, the impacts could be negligible or small or even positive depending on the rate of replacement.	Temporary
Social Environment			
13	Resettlement/Land Acquisition	Loss of agricultural land and properties (Detailed Survey will be done to identify the PAPs). Out of the total length of 529.450 km of proposed Silver Line rail alignment, approx. 40% of the total length is parallel to the existing railway as well as within the designated land of MoR in order to minimize involuntary resettlement. Most of the alignment from Thiruvananthapuram to Tirur is proposed in greenfield areas. However, since land acquisition of private land is still necessary, a certain degree of involuntary resettlement is inevitable.	Permanent

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
14	Local economies, such as employment, livelihood, etc	Overall construction activities together with traffic restrictions would disturb local economic activities to some extent. On the other hand, the construction activity will create job opportunities for the local people.	Temporary
15	Cultural Heritage	Religious places which usually require silence might be affected by noise and vibration from operation of construction equipments and vehicles in some areas. In addition, access to religious places might be disturbed by construction works and traffic restriction.	Temporary
16	Socially vulnerable groups such as the poor, indigenous and ethnic people	Construction works, traffic restriction and design layout of proposed Silver Line rail plan (construction in front of station, track passing through or near residential or market area etc.) could cause inconveniences to disabled people, children, and women in the construction areas.	Temporary
B: During Operation Phase			
Natural Environment			
1	Topography and Geology	No adverse impact is envisaged.	Permanent
2	Hydrology	No adverse impact on hydrology is envisaged.	Permanent
3	Local Meteorological Condition	The project does not have any factor which may affect and/or be related to the meteorology.	Temporary
4	Landscape	Appearance of the proposed Silver Line rail alignment and related facilities would change the landscape from prior one, in and around the project site.	Permanent
5	Protected Areas /Sanctuaries	No adverse impact is envisaged.	Permanent

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
6	Ecosystem	Birds and animal movements in these areas are likely affected by the embankment and movement of trains	Permanent /Temporary
Pollution Control			
7	Air Environment	A reduction of emissions from vehicles would be expected overall due to the reduction of traffic congestion and traffic volume by changing/shifting transportation mode from road to the proposed Silver Line rail system.	Temporary
8	Noise & Vibration	Operation of the trains would cause noise along the railway track. Religious, educational and health places near the Silver Line rail corridor and relevant facilities may be particularly sensitive to the noise and vibration of the Silver Line trains.	Temporary
9	Water Environment	Effluents containing oil/chemicals from depots and workshop and domestic wastewater from trains and stations could affect water bodies nearby in the cases of direct discharge without pre- treatment or without connection to the sewerage system	Temporary
10	Land Environment	No major impact is expected.	Temporary
11	Bottom Sediment	No adverse impact is envisaged.	Temporary
12	Global Warming	The change/shift of transport mode from fossil fuel used automobile to electrified railway system, significant reduction of emissions of greenhouse gas such as CO_2 will be expected per unit transport distance per person.	Temporary
Social Environment			
13	Resettlement/Land Acquisition	No adverse impact is envisaged.	Permanent

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact
14	Local economies, such as employment, livelihood, etc	The regional economy, particularly industrial sectors in major industrial locations is expected to be improved due to smooth fast transportation. Besides, the Silver Line rail project is also expected to create new employment and business opportunities in the state.	Temporary
15	Cultural Heritage	Religious places near the proposed Silver Line rail alignment and relevant facilities might be affected by noise and vibration due to operation of the Silver Line.	Temporary
16	Socially vulnerable groups such as the poor, indigenous and ethnic people	The project could cause inconveniences for the physically disabled.	Temporary
C: Positive Impacts			
1	Employment Opportunities	Positive impact	Permanent
2	Benefits to Economy and social life of the people.	Positive impact	Permanent
3	Reduction in road traffic congestion	Positive impact	Permanent
4	Less Fuel Consumption	Positive impact	Permanent
5	Reduction in air pollution and GHG emission	Positive impact	Permanent
6	Traffic Noise Reduction	Positive impact	Permanent

14.5.2 Positive Environmental & Social Impacts

Construction Phase

During the construction period, there is a likelihood of having the following impacts;

14.5.2.1 Creation of employment opportunities

There are 50,000 direct and indirect employment opportunities envisaged during construction period and 10,000 during post project operation period. Many job opportunities will be available for construction workers during the construction phase of the project. Employment opportunities are a benefit both in economic and social sense. For the construction development un-skilled labour, from the local community, will be hired. Although only during the duration of the project, several workers including casual labourers, masons, carpenters, joiners, electricians and plumbers are expected to work on the site during the construction. Thus, as a result the project would provide substantial direct employment. In addition to these, more people would be indirectly employed for allied activities.

14.5.2.2 Increased trade with construction workers

The construction workers required for the project will provide ready market for various goods and services, leading to several business opportunities for small-scale traders such as shop owners, accommodation providers, and food vendors near the project site.

14.5.2.3 Business opportunities in supply of materials and utilities

This project will require large quantities of construction materials, which will increase revenue for local businesses at project corridor area, such as cement, steel, and other miscellaneous materials required for construction that can be sourced locally.

14.5.2.4 Less Land Requirement

The land requirement for a double track rail corridor is 15 to 25m wide RoW which is 3 times less than the requirement for construction of 6 lane highway to cater same amount of traffic. The total estimated corridor length is about 529.450 km. Wherever the corridor is crossing the backwaters or rivers, it will cross through viaduct. Adequate clearance shall be provided under viaduct for passage of boats and ferries.

Operational Phase

During the operation phase the following positive impacts are foreseen:

14.5.2.5 Improved transport efficiency for people

The operation of Silver Line rail corridor and railway stations will improve efficiency of transportation of people, it will also improve connectivity within the major towns of Kerala state. The project will result in direct benefits to users in terms of reduction in vehicle operating costs, savings in travel time, improvement in quality of life, reduction in loss of productivity due to health disorders resulting from pollution and last but not the least substantial reduction in road accidents.

In the present context, the project will streamline and facilitate movement of public from different parts of Kerala. Average speed of travel (Thiruvananthapuram – Kasaragod) is expected to be 130 kmph approximate depending on the type of service (slow, express and very fast) compared to 40 kmph to 60 kmph on the existing main line Railway. The average speed of travel on the existing highway (NH-66) is also at 30 kmph to 40 kmph. So, the Silver Line rail has the potential to greatly improve transportation and benefit the economy and social life of the people of Kerala. It will greatly improve the opportunity for education and employment, by improving travel to the major universities, colleges and industrial hubs. Stations shall be provided at the following places: Thiruvananthapuram, Kollam, Chengannur, Kottayam, Ernakulam, Kochi Airport, Thrissur, Tirur, Kozhikode, Kannur and Kasaragod. This corridor will yield benefits in terms of growth in economic activity due to better accessibility, savings in fuel consumption, corresponding reduction in cost of road construction and maintenance, reduction in vehicle operating costs, savings in travel time, improvement in quality of life and reduction in loss of productivity due to health disorders resulting from pollution.

14.5.2.6 Benefits to Economy and Socio – Economic Status

The Silver Line rail will connect eleven major towns and cities of Kerala including Kochi Airport and six most populated cities of the state i.e. Thiruvananthapuram, Kollam, Ernakulam, Thrissur, Kozhikode and Kannur. The operation of rail corridor will lead to easy accessibility for all major towns, thereby attracting new investors and traders in the area. By providing Silver Line connectivity at Kochi Airport will encourage transit oriented development in the area. This will translate to economic growth in the area. Additionally, increased presence of investors will have the potential to increase land value for property owners near the railway stations area.

During construction, the project will have clear benefits about local employment opportunities. The project will additionally require various skills and services which may not be available on the local level but certainly on the regional level, e.g. pipe fitters, plumbers, etc. for which appropriate personnel will be contracted.

The increase in employment will temporarily lead to an overall increase of income directly and indirectly (through increased demand of other local services). New businesses will grow such as food vending to construction workers.

14.5.2.7 Improved trade

The trade from and to the city will be improved and this will also give an opportunity for opening the area around the project site to trade. In addition to opening the trade centres, the delivery of farm produce, like vegetables, fruits livestock to market centres will be more efficient. Livestock and crop trade are expected to increase because of the ease of transportation coupled with the reduced cost and time of travel.

14.5.2.8 Enhanced delivery of services

This is a long-term impact due to the opening of the Silver Line rail corridor, resulting in improved access to social services e.g. health facilities, education opportunities, etc.

14.5.2.9 Reduction of congestion and accidents on Road

One of the key aims of this project is to decongest the highways and decrease the bus and car circulation between Thiruvananthapuram to Kasaragod through an efficient rail transport. The basis of reduction of vehicle is shift of ridership from road vehicle to the Silver Line rail. The reduction in number of vehicles gives benefits to economy by reduction in Vehicle Operating Cost (VOC), Fuel Consumption, Pollution Load, Accidents and Travel Time etc. On implementation of the project, the consumption of petrol and diesel will get reduced. Summary of daily ridership on the Silver Line, considering the probability of shift from the respective mode of transport (i.e. bus, car and train) is shown in below Table 14-38.

Table 14-38: Summary of Ridership – Realistic Scenario

Horizon Year	Daily Ridership
2025 – 26	79934
2029 – 30	94672
2041 – 42	132944
2052 – 53	158946

14.5.2.10 Reduction in air pollution from vehicle emissions

Reduction and decongestions of vehicles on the highways translate to reduction of air pollution brought about by emissions from vehicles. The major vehicular air pollutants are Particulate Matter, Nitrogen oxides, Carbon monoxide, Hydro Carbons and Carbon dioxide. In addition, un-burnt products like aldehydes, formaldehydes, acrolein, acetaldehyde and smoke are by-products of vehicular emissions.

Deaths per 1,00,000 people from ambient PM $_{2.5}$ in South Asia (Bangladesh, India, Nepal and Pakistan) in year 2013 was 51. Welfare losses from ambient $PM_{2.5}$ in South Asia in year 2013 was estimated at USD 256 billion or 3.1% of GDP; respective labour output foregone was estimated at USD 31.4 billion or 0.39% of GDP.

Welfare losses from air pollution in India in year 2013 was estimated at USD 505 billion and labour output foregone was estimated at USD 55 billion (The cost of air pollution - Strengthening the Economic Case for Action, World Bank IHME 2016).

14.5.2.11 Impact on Green House Gas (GHG) Emission

Road transport, the dominant mode of transport in India, emits 87% of total CO_2e emissions from the transport sector. The rail transport in comparison to all mode of transport emits only 5% of the total CO_2e emissions. As per the traffic survey conducted in the year 2019 at 18 locations along the project influence area between Thiruvananthapuram to Kasaragod, the GHG emission has been estimated to be 3055234 Tonnes CO_2e in 2019 and it will be 4601434 Tonnes CO_2e in year 2024, without Silver Line rail operation.

The Silver Line rail will reduce GHG emissions in the state by giving travellers a more efficient option for mid- to long-range trips. Every kilometre travelled on semi high-speed rail is a kilometre not travelled by automobile. The emissions associated with these less-efficient forms of travel will be significantly reduced. The GHG emission reductions is associated with the mode shift from conventional rail, cars, buses and trucks. The Silver Line rail corridor will reduce emissions from 2025 – 26 onwards, the first year of operation, as passengers switch over from conventional rail, cars and buses to Silver Line rail. The annual GHG emission reductions forecasted for the horizon years 2025 – 26, 2029 – 30, 2041 – 42, and 2052 – 53 are presented in Table 14-39. GHG savings are worked out as per the projected ridership. GHG savings are directly related to ridership. Higher the ridership, greater the GHG emission savings.

Table 14-39: GHG Emission Reduction

Horizon Year	Greenhouse Gas Reduction (Tonnes CO_2e/Year)
2025 – 26	287994
2029 – 30	351940
2041 – 42	497124
2052 – 53	594636

Source: EIA Study Team

The annual amount of GHG emission reductions (car, bus, truck and rail) as carbon dioxide equivalent emission are calculated by using a ton of emission in one year (tCO_2e/year). The GHG emission reduction from car, bus, truck and rail for the horizon year 2025 – 26 are presented in the Table 14-40 to 14-46. The calculation of the carbon dioxide emission is according to the below formula;

Carbon Dioxide equivalent emission for a year = {No of Vehicle/Trips/Pax * Distance (km) * EF for GHS Emission * GWP for the GHG * 365}

Table 14-40: Adopted CO_2 Emission Factors

Types of Vehicles	CO_2 (g/km)	CH_4 (g/km)	N_2O (g/km)
Diesel Car	148.87	0.00031	0.000621
Petrol Car	155.88	0.01075	0.002236
Freight Transport	736.6	3.169	2.982
	CO_2 (g/pax-km)	**CH_4 (g/pax-km)**	**N_2O (g/pax-km)**
Bus Transport	15.161	0.000807	0.000559
Rail	0.00794 kgCO_2/Pax-km		

Source: IPCC and India GHG Program

Table 14-41: GHGs Controlled Under the Kyoto Protocol and Global Warming Potential

Sl. No.	Greenhouse Gas	GWP (Carbon Dioxide Equivalent)
1	Carbon dioxide (CO_2)	1
2	Methane (CH_4)	25
3	Nitrous oxide (N_2O)	298

Source: IPCC

Table 14-42: GHG emission reductions by Diesel Car (2025 – 26)

No. of Vehicles	Distance (km)	CO_2 as Tonnes CO_2e	CH_4 as Tonnes CO_2e	N_2O as Tonnes CO_2e	Tonnes Co_2e/year
4906	74	19726.92	1.026961	24.52223	19752.47
5098	63.1	17479.51	0.909963	21.72851	17502.15
5354	35.9	10444.14	0.54371	12.98295	10457.67
5119	72.8	20249.61	1.054171	25.17197	20275.83
5590	37.4	11360.13	0.591395	14.12161	11374.85
5679	53.7	16570.9	0.862662	20.59904	16592.37
5168	70.9	19909.89	1.036486	24.74967	19935.67
5515	53.5	16032.43	0.83463	19.92967	16053.19
2996	92	14977.17	0.779694	18.61789	14996.57
1021	95.9	5320.401	0.276974	6.613709	5327.292
Total					**152268.1**

Table 14-43: GHG emission reductions by Petrol Car (2025 – 26)

No. of Vehicles	Distance (km)	CO_2 as Tonnes CO_2e	CH_4 as Tonnes CO_2e	N_2O as Tonnes CO_2e	Tonnes Co_2e/year
2102	74	8850.09	15.25829	37.83079	8903.179
2185	63.1	7844.478	13.52453	33.53218	7891.535
2293	35.9	4683.621	8.07495	20.02071	4711.717
2194	72.8	9087.643	15.66785	38.84623	9142.157

No. of Vehicles	Distance (km)	CO_2 as Tonnes CO_2e	CH_4 as Tonnes CO_2e	N_2O as Tonnes CO_2e	Tonnes Co_2e/year
2396	37.4	5098.491	8.79022	21.79412	5129.076
2434	53.7	7436.663	12.82142	31.78892	7481.274
2215	70.9	8935.178	15.40499	38.19451	8988.778
2364	53.5	7195.89	12.40631	30.75971	7239.056
1284	92	6721.034	11.58762	28.72988	6761.352
438	95.9	2389.879	4.120349	10.21583	2404.216
Total					**68652.34**

Table 14-44: GHG emission reductions by Bus (2025 – 26)

No. of Vehicles	Distance (km)	CO_2 as Tonnes CO_2e	CH_4 as Tonnes CO_2e	N_2O as Tonnes CO_2e	Tonnes Co_2e/year
7553	74	3092.943	4.115832	33.98382	3131.043
7850	63.1	2741.067	3.647585	30.11757	2774.833
8237	35.9	1636.38	2.177559	17.97978	1656.538
7882	72.8	3175.327	4.225462	34.88902	3214.442
8607	37.4	1781.329	2.370445	19.57241	1803.272
8744	53.7	2598.395	3.457728	28.54995	2630.403
7958	70.9	3122.273	4.154862	34.30608	3160.734
8492	53.5	2514.111	3.34557	27.62388	2545.081
4613	92	2348.508	3.125199	25.80431	2377.437
1573	95.9	834.7723	1.110846	9.172089	845.0553
Total					**24138.84**

Table 14-45: GHG emission reductions by Truck (2025 – 26)

No. of Vehicles	Distance (km)	CO_2 as Tonnes CO_2e	CH_4 as Tonnes CO_2e	N_2O as Tonnes CO_2e	Tonnes Co_2e/year
457	532.8	65464.37	7.04102	78.976	65550.38776

Table 14-46: GHG emission reductions by shifting of Train Passenger (2025 – 26)

No. of Pax	Distance (km)	Tonnes CO_2e/year
7369	74	1580.351
7657	63.1	1400.236
8035	35.9	835.9758
7688	72.8	1622.027
8396	37.4	910.0335
8530	53.7	1327.507
7762	70.9	1594.899
8283	53.5	1284.265
4501	92	1200.08
1534	95.9	426.3412
Total		**12181.72**

GHG Emission due to Energy consumption (2025 – 26) : 34797.9247 TonnesCO_2e.

Net GHG Emission Reductions (2025 – 26) = [(GHG Emission reductions by diesel car+ GHG Emission reductions by petrol car+ GHG Emission reductions by bus+ GHG Emission reductions by trucks+ GHG Emission reductions by shifting of existing rail passenger) - GHG Emission due to energy consumption].

Net GHG Emission Reductions (2025 – 26) in TonnesCO_2e

= [(152268.1+68652.34+24138.84+65550.39+12181.72) – 34797.92] = 287993.47

14.5.2.12 Impact on Climate Change

The transport sector has been regarded as one of the main culprits for the rise in global temperature due to the emissions coming from various types of motorized transportation used by people. The alarming performance of the transport sector is largely due to road traffic, which accounts for 73% and aviation is the second largest emitter accounting for 13% of global transport CO_2 emissions. In comparison to all mode of transport, the rail sector accounts for just 2% of total transport emissions. Nevertheless, to improve access, transit, and safety, the investment in land transport, such as roads and rail, has been growing. Silver Line rail offers tangible advantages over other transport modes such as air, existing rail and private vehicles for medium to long distance journeys. Considering the evaluation of complete life cycle of transportation systems in terms of sustainability, Silver Line Rail is one of the greener and most efficient mode of transport.

Rail Transport is a highly competitive energy efficient means of transport in that its consumption of energy per unit load per km is lower than road and air modes. With CO_2 emissions from transport being dominated by road and air, rail being a low carbon transport mode offering a great potential for decarbonizing transport, rail is called to play an important role in the fight against climate change. The annual GHG emission reductions by the implementation of Silver Line project is presented in Table 14-39.

The Silver Line Corridor is a step in that direction with the objectives of (i) to reduce the travel time between Thiruvananthapuram and Kasaragod; (ii) to provide a comfortable and safe transportation opportunity; and (iii) to increase the share of railway in the national transportation network.

The third above mentioned objective of Silver Line Project is relevant to mitigating climate change as this will result in lessening the use of non-mass transport system which eventually results in less emission to the atmosphere from private vehicles. The minimization of emissions is an important step in improving air quality and decreasing contribution to emerging problem and threat of climate change.

14.5.2.13 Aesthetic quality

The new rail corridor as well as new railway station, with its associated access road and other amenities will improve the aesthetics of the area, leading to improvement from its current situation.

14.5.2.14 Revenue to national and local governments

Through payment of relevant taxes, rates and fees to the government and the local authority, the project will contribute towards the national and local revenue earnings from those using the improved facilities, and any resultant increase from economic activities brought about by the improved situation.

14.5.2.15 Improved Drainage

One of the key enhancements of the railway station is the drainage system. It will integrate the existing infrastructure and topography such that it efficiently manages the surface runoff and avoid flooding at the station during heavy rains.

14.5.2.16 Improved Security

The access road to the railway station and its amenities such as pedestrian footpaths, street and flood lights will enhance the security in the area, which is currently lacking for commuters. This will encourage more commuters served by the station and the surrounding areas to use the railway transport.

14.5.2.17 Tourism

By providing faster intercity travel along the coastal belt which is known for endless beaches, famous backwaters of Kollam, Thiruvananthapuram, Varkala, Alleppey, Kochi, Thrissur, Kozhikode, Kannur, Bekal and Kasaragod, the Silver Line rail will boost tourism. Access to the major religious places such as Sree Padmanabha Swami temple at Thiruvananthapuram, Vadakkunnathan Temple at Thrissur, and Guruvayoor Lord Krishna Temple near Thrissur will also attract tourism with Silver Line. Travel on Silver Line rail itself is likely to become a tourist attraction.

14.5.3 Negative Environmental & Social Impacts

Anticipated negative impacts due to various activities envisaged during construction and operation of Silver Line rail corridor have been assessed and further mitigation measures have been suggested for each of the following environmental components.

- Air Environment
- Noise Environment
- Water Environment
- Land Environment
- Biological Environment
- Hydrology
- Landslides
- Rolling Stock
- Socio-economic Environment

14.5.3.1 Air Environment

The air environment in the proposed Silver Line rail corridor will be affected by various factors including the design, process technology, raw materials used, envisaged emission control measures, transportation of raw materials and products, storage facilities and material handling, and operation and maintenance practices.

14.5.3.1.1 Air Environment: Impact during Construction Phase

During the construction phase, the impact on ambient air quality is envisaged due to fugitive dust emission coming out of the construction site. However, this impact would be of temporary nature and will be localized. The Silver Line rail corridor is relatively clean, and no major source of air pollution is reported along the route. The major pollutant in the construction phase is dust/PM_{10} being air-borne due to various construction activities. Various construction activities that may contribute to air pollution during construction phase are dust generation due to earthmoving and construction work; transportation of construction materials; Dust generation at burrow areas; quarrying activities; construction machinery viz., DG sets, Concrete mixers, etc. The vehicular movement generates pollutants such as NO_X, CO and HC. Emissions from vehicles and machinery could also impact quality of air in and around construction sites.

14.5.3.1.2 Air Environment: Possible Impact during Operational Phase

No major adverse impact on air quality is envisaged in the operation phase except corridor effect on air movement along the Silver Line rail alignment due to semi-high-speed train movement. The adverse impact on air quality is envisaged from the station and maintenance depot in the form of gaseous and particulate emission from DG set. Air pollution in the vicinity of stations can be expected due to movement of vehicles coming/going out of the station. Ambient Air quality in the vicinity of the stations needs to be monitored on regular basis during operation phase for PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO.

14.5.3.1.3 Mitigation measures on Air Environment

- Maintain all construction vehicles to minimize vehicle emissions.
- Payload area of the trucks or dumpers should be covered by tarpaulin when transporting soil and crush in order to prevent fall out of fines and emissions of dust.
- Spray water on the stones while unloading from the truck/dumper, at the primary crusher feeder chute and the transfer points from one belt conveyor to another, etc.
- Facility for regular cleaning and wetting of the unpaved roads and exposed soil on construction sites should be provided in dry weather.
- Trees should be planted to develop a green belt within and along the boundary of the yards and corridor.
- Concrete batching plant or other machinery liable to generate dust should be kept away at safer distance from residential areas and should not be in predominant upwind direction of these areas.
- Ensure that all major construction machineries including batching plant placed on construction sites are inbuilt with appropriate dust reduction measures.
- The haul freight corridors inside the quarry should be properly watered to arrest the dust arising out of it.
- Conduct periodic monitoring of ambient air quality as per NAAQS, 2009
- Provide adequate height of the stack of DG set to have wider dispersion of the gaseous emission and to attain the mixing height.

14.5.3.2 Noise & Vibration Environment

Noise and vibration are among the major concerns about the effects of a semi-high-speed rail project on the surrounding community. A field review of the existing and proposed land uses within 500 m on either side of the proposed alignment and construction sites was undertaken for identifying the nature and location of sensitive receptors.

14.5.3.2.1 Noise & Vibration: Impact during Construction Phase

During the construction phase, noise will be generated due to movement of vehicles, and operation of light & heavy construction machineries including pneumatic tools (dozers, tippers, loaders, excavators, graders, roller, concrete mixer, generators, concreting pumps, vibrators, cranes, compressors etc.).

Workers working at noisy areas may be affected (if they do not use ear muffs/plugs), if actual exposure exceeds the prescribed safety limits (8-hour long limit of 90 dB (A)) as per Factories Act / BOCW Act 1996.

Construction activities can result in varying degrees of ground vibration, depending on the equipment and methods employed. Ground vibrations from construction activities do not often reach the levels that can damage structures, but they can achieve the audible and feelable ranges in buildings very close to the site. The construction activities that typically generate the most severe vibrations are blasting and impact pile.

14.5.3.2.2 Noise & Vibration: Impact during Operational Phase

The frequent train movements would generate a certain level of noise and vibration. The generated noise and vibration may cause sleep disturbance and mental instabilities of the residents living adjacent to the proposed alignment. In addition, careful attentions should be paid on noise impacts on sensitive receptors (SRs) located near the proposed alignment such as educational institution, hospitals and religious institutions. In absence of the Indian Guidelines for assessment of impacts of Noise and Vibration due to running of Semi High Speed Train, the available guidance manual of Federal Transit Administration (FTA) and Federal Railroad Administration (FRA) on noise and vibration has been used for the assessment of impacts of noise and vibration due to operation of Silver Line rail.

In operation phase, there will be significant movement of vehicles at the stations for passengers, and continuous movement of vehicles will be a source of noise & vibration generation. The public needs to be made aware about the noise generation and various possible options for mitigation of the same.

14.5.3.2.3 Noise & Vibration: Mitigation Measures

- Notify the local people prior to undertake the construction activities associating with higher noise and vibration level such as blasting operations.
- Locate the quarry sites away from the residential areas and sensitive receptors.
- Avoid night time construction in residential neighbourhoods.
- Use low-noise designed; Machinery and vehicles should be maintained regularly, with particular attention to silencers and mufflers, to keep construction noise levels to minimum.
- Re-route construction-related truck traffic along roadways that will cause the least disturbance to residents.
- Prohibit aboveground jack hammering and impact pile driving during night time hours near residential areas.
- Use high-grade engine exhaust silencers and engine-casing sound insulation.
- Protection devices (ear plugs or ear muffs) should be provided to the workers operating in the vicinity of high noise generating machines.

- Expanding the right of way (buffer zone) is recommended method of reducing the noise impact and a vegetative barrier in the buffer zone will be helping to reduce the noise impact.
- Noise barriers should be erected at appropriate locations such as residential areas and sensitive receptors which are adjacent to the corridor.
- Avoid impact piling in vibration sensitive areas. Drill pile or sonic piling will be employed in such areas to reduce the impacts on nearby buildings.
- The vibrations should be reduced considerably by ensuring and keeping correct track geometry by advanced measurement.
- Noise and Vibration monitoring will be undertaken as suggested in the environmental monitoring plan and a plan shall be prepared by the contractor to control the damage due to vibration**.**

14.5.3.3 Water Environment

14.5.3.3.1 Impact during Construction Phase

Water pollution is likely occurred mainly by the construction activities. Impacts on the water quality would be brought not only by the construction activities itself, but also the discharge of wastewater and materials into surface water bodies from the workers being temporarily housed for the construction. The deterioration of surface and ground water quality is expected if adequate arrangements are not made to ensure proper control and management of drainage of water and wastewater from the construction yards and camp sites including water form stagnant pools. Stagnant pools of water may promote the breeding of mosquitoes and create generally unsanitary conditions. Surface water would become polluted if sediment is washed from construction sites, roads and other exposed soil by rainfall. River water would be also polluted by sediment if sand or aggregate are obtained from the riverbeds. Soil compaction can also occur as a result of construction activities. Soil compaction causes a reduction in the volume of water permeating into the ground therefore increasing run-off. The run-off would normally contain suspended silt as the compacted ground would be susceptible to erosion in the absence of vegetation cover.

On the other hand, water pollution is likely occurred by used petroleum, oil and lubricant products that may have entered the drainage system from maintenance activities etc.

14.5.3.3.2 Impact during Operation Phase

Maintenance from sub-depos at intervals along the alignment will maintain and repair track, catenary and other elements. This work would pollute river water with residual oil, grease and iron fillings etc.

14.5.3.3.3 Mitigation measures on Water Environment

Following measures are suggested to mitigate adverse impacts on land environment during construction and operation phases.

- Identification of water sources should include a quick assessment to identify capacities to maintain water requirement of competing users;
- All necessary statutory approvals should be secured from local authorities (Irrigation department for rivers / lakes and LSGs for wells);
- All applicable water quality standards should be complied with, at all construction sites along the proposed alignment route during the entire period of construction activity;
- It should be ensured that no liquid is discharged from any construction site/activity without treatment;
- Stockpiled soil and other loose material should be covered with secure tarpaulins;
- As far as possible, all parking, repair and fuel storage areas should be located away from water bodies;
- Effective storm water drainage system should be provided in every bridge to eliminate / reduce the chance of discharge of untreated storm water directly into the river;
- Measures should be adopted to avoid contact between water and machinery when construction work is conducted in rivers, streams and canals;
- All hazardous materials on-site should be stored in areas with concrete floors enclosed by concrete bunds;
- Oil catch pit/ oil trap may be erected along drain channel from construction site to prevent oily water to flow into any water body;
- Greening of the excavated area to prevent erosion of soil is one of the mitigation measures on the content;
- Silt fencing may be provided near water bodies;
- Proper sanitation facilities shall be provided at the construction site to prevent health related problems due to water contamination.
- Where there is no possibility for getting surface water for the construction, the ground water will be tapped after obtaining necessary permission from the authorities concerned such as Central Ground Water Authority (CGWA).
- The water course should not be blocked while constructing the corridor, but suitable culverts and drains should be provided for the free flow of water.
- Implement suitable measures to minimize usage of water as well as reduce wastage.
- To reduce the fresh water demand, recycle mechanism shall be adopted.
- Treated water from STP shall be used for construction.

14.5.3.4 Land Environment

14.5.3.4.1 Impact during Construction Phase

Physico-chemical changes in soil quality may occur during construction mainly due to clearing of vegetative cover along the Silver Line route and at the stations, workshop & depot, which may cause temporary soil erosion resulting in turbidity in surface run-off. Movement of vehicle / machinery / equipments and working force is also likely to cause soil erosion. Loosening of top soil and loss of vegetative cover from the RoW section due to excavation, cutting and backfilling could lead to soil erosion. Construction & demolition waste (debris, unused iron bars or damaged support structures, quarry dust) may affect soil at the site, if such wastes are disposed in an uncontrolled manner. Soil may get contaminated due to inappropriate disposal of liquid waste (vehicle/equipment washing effluent) from construction sites. Oil spills from the operation of the diesel generator/ pump and diesel storage, during transportation and transfer, parking places and diesel generator sets may have impacts on soil at location of spillage. Spill or uncontrolled disposal of waste lubricating oil and grease, vehicular maintenance waste (fuel filters, oily rags, soiled non-usable parts), uncontrolled disposal of domestic solid waste and sewage from construction camps can result in land pollution.

14.5.3.4.2 Impact during Operation Phase

No soil erosion is envisaged when the Silver Line rail is in operation as all the slopes and embankments of the project shall be stabilised through sound engineering techniques. Due to change in land use, impact is envisaged on soil during operation phase. However, the impacts are within the RoW.

14.5.3.4.3 Mitigation measures on Land Environment

Following measures are proposed to mitigate adverse impacts on land environment during construction phase:

- Suitable protection measures consisting of bio-engineering techniques such as plantation of grass and shrubs, may be provided to control erosion. The measures shall be applied along the slopes at high embankment where bridges will be constructed.
- Temporary drainage channels will be provided to minimize soil erosion
- Construction work may be avoided during rainy season to evade erosion and spreading of loose material.
- Borrow areas may be finalized in concern with ecological sensitivity of the area. Agriculture land may not be used as borrow areas. Priority may be given to degraded area for excavation of borrows material. Rehabilitation of borrow area may be taken under the project.

- Selection of borrow areas may be done considering the waste land available in the district. Agricultural areas may be not used as borrow areas.
- A separate borrow area management plan may be made providing location, ownership details, timing of borrowing and rehabilitation measures.
- Top soil removed from agricultural land may be stored separately in bunded areas and utilized during plantation or refilling of excavated area.
- Land will be reinstated after completing the construction activity using the preserved top soil.
- Excavation and filling operation should be carried out in parallel to minimize the soil erosion.
- The fuel shall be stored in separately designated area with RCC surface to prevent any soil contamination due to spillage.
- Overflow of service and washing areas shall be pass through from oil interceptors.
- Septic tank with soak pit facility will be provide in labour camps to prevent any soil contamination due to sewage discharge.
- Waste management system will be adopted in construction camps.
- Centralized waste management facility at different sections along the route is recommended to collect all the construction waste during construction phase for subsequent safe utilization/ disposal. This will help to avoid the lying of material all along the construction route.
- On completion of construction works all temporary structures, surplus materials and wastes will be completely removed to avoid future land use incompatibility. Dumping of construction waste on agricultural land will be prohibited and stockpiles will be provided with gentle slopes.
- Air quality including noise & vibration monitoring should be carried out during construction phase. If monitored parameters are above the prescribed limit, suitable control measures need to be taken
- Mask and other necessary protective gears should be provided to the all construction workers.
- No impact is envisaged on soil during operation phase. Any damage or breach in embankment shall be repaired immediately.

14.5.3.5 Biological Environment

14.5.3.5.1 Impact on Flora during Construction Phase

The Silver Line corridor is not passing through any reserved or protected forest. There are no threatened or endangered plant species or habitats for such species known to be within the RoW. The major impact in this project on flora involves the removal of trees growing within the RoW (on both private and public lands) for efficient construction workmanship and to provide clear zone for safety of the users. Trees, herbs and shrubs in the RoW will be felled along the alignment route could adversely affect vegetation cover and local landscape.

14.5.3.5.2 Impact on Flora during Operation Phase

No impact envisaged on flora during operation phase. Improper post-plantation care/ maintenance as well as illegal felling of plantation along the track will offset all positive efforts by the project.

14.5.3.5.3 Flora: Mitigation Measures

- Cutting of trees will be minimized wherever possible. Compensatory afforestation will be done by transplanting & planting trees.
- All the trees which can be technically replanted shall be transplanted with treespade technology.
- The management plans for transplantation of trees includes Preliminary root investigation, Health diagnosis, Soil condition, regular monitoring for fertilizer schedules, etc.
- Appropriate compensatory plantation using suitable native species or pollution tolerant species should be initiated to compensate for the vegetation loss due to felling of trees during site clearing.
- For trees to be felled in private land, compensation for trees based on fruit yield value, timber value and other economic value should be given to the owners
- For mangrove felling, permission from the State Forest Department shall be secured. Compensatory mangrove plantation shall be taken up at the identified location in consultation with the Forest Department.
- Plantation along the RoW should be maintained properly (in terms of proper inspection/ pruning, water and nutrition requirements) as well as protected from illegal felling

14.5.3.5.4 Impact on Fauna during Construction Phase

Terrestrial, aquatic and avifauna may be affected in the construction phase by noise and vibration due to construction equipment and machinery as well as movement of construction bound vehicles. Removal of trees along the proposed alignment route will lead to the destruction of faunal habitats such as bird nests, breeding sites, *etc*. Increased sediment loads into water bodies during bridge construction work may impact aquatic fauna due to temporary loss of habitat and reduced water quality and flow.

14.5.3.5.5 Impact on Fauna during Operational Phase

Proposed Silver Line rail which may divide the natural habitats in certain landscape that could possibly affect faunal population range and distribution, ability to mate, connectivity between populations. Impact on aquatic fauna in case of accidental oil spill and toxic chemicals release find its way into the water bodies. The noise and vibration generated by the Silver Line rail project may disturb the fauna including domestic livestock especially in the night time. There is a potential of direct impact of Silver Line trains hitting avifauna since the trains will be running at a speed of 200 km/h on viaduct at a height of 10m-15m.

14.5.3.5.6 Fauna: Mitigation Measures

- Noise and vibration at the construction site should be minimized and all major noise producing construction equipment/ machineries should be fitted with acoustic control measures
- Soil compaction for embankment work should be done immediately to avoid erosion and consequently increase in sediment loads to the water bodies.
- Major earth work during construction of important bridges should be done during the dry period.
- Immediate actions should be taken for speedy cleaning up of oil spills, fuel and toxic chemicals in the event of accidents.
- Crossing structures should be constructed at regular interval and the location, frequency, basic design and number of crossing structures need to be finalised in consultation with various stakeholders.

14.5.3.6 Impacts on Hydrology

The project is a linear one/ crossing all the west flowing rivers, streams of Kerala and agriculture fields/ flood plains are crossed or runs along. Large quantity of earthwork involved affects Hydrological environment. Embankments cause Inundation/ obstruct easy flow downstream, increase silt flow, etc. Increase in soil erosion hampers the water quality/increased siltation. Reduced infiltration resulting in increase in surface flow and resultant flood. Obstruction of flow due to banking also result in ground water fluctuation and water logging. Kollam and Kasaragod (station/yard) are identified as the most vulnerable place of hydrological impact.

14.5.3.6.1 Hydrology: Mitigation Measures

- The rail track shall be designed and constructed in such a way as to maintain natural waterflow and drainage patterns to the extent practicable. This shall be include placing of equalization culverts through the embankment as necessary, preventing impoundment of water or excessive drainage and maintaining the connectivity of floodplains and wetlands.
- Bridges and Culverts shall be designed, constructed, and operated to maintain existing water pattern and flow conditions as practicable.
- Culverts shall be designed and constructed for stream crossing with the width greater than or equal to 125 percent of the width of the stream at the ordinary high water stage.

- Whenever possible, culvert shall be buried to approximately 40% of their diameter with substrate material that would remain stable at expected flood discharge rates.
- High Flood water discharge VENT has to be provided for Bridges/Viaducts.
- Some banking may be changed to VIADUCT in Severe hydrological impact zones.
- Suitable Irrigation canal crossing structures shall be designed.
- Banking shall be with adequate cross drainage to avoid water logging.
- In Kollam and Kasaragod (station/yard) diversion of *thodu* shall be done after comprehensive hydrological study.
- Minimized siting construction staging and access areas and temporary fill within a floodplain and sensitive areas.
- During construction, a combination of temporary and permanent detention basins, notched weirs, swales and vegetative strips would be used to limit off-site stormwater runoff.
- Access roads would be constructed so that the length of each road crossing minimizes any adverse effects on water (e.g., the shortest crossing distance would be used) and would be as near as possible to pre-construction contours and elevations.

14.5.3.7 Impact of Landslides

Landslides mostly occur in areas having unstable slope i.e., a surface having one end or side at a higher level than another. They often take place in conjunction with heavy rainfall, earthquakes, floods, cloud burst, mining, excavation, erosion or with loading/unloading of slopes.

When slope forming materials that constitute mass of rock, debris or earth, moves downwards and outwards, under the influence of gravity and triggered by various factors, it is termed as landslide.

Studies conducted in the state indicate that prolonged and intense rainfall or more particularly a combination of the two and the resultant persistence and variations of pore pressure is the most important trigger of landslides. The study reveals that 1848 km^2 (4.71%) of the state is under high and 3759 km^2 (9.77%) under low hazard category.

All 13 districts, except Alappuzha in the state falls under low and high landslide prone area. Kozhikode is prone to deep seated landslides while Kottayam is prone to shallow landslides. The most common type of landslide in Kerala is debris flows. The Silver Line rail corridor is passing through 11districts of the state.

14.5.3.7.1 Mitigation Measures

Landslides can be moderated, if proper measures while construction and before taking up a construction are considered. Following landslide preventive techniques are recommended;

- The alignment preferably to be located as to avoid terrain that is inherently unsuitable for laying a Railway line, such as landslide-prone areas and unstable hill slopes, geological fault lines and other major discontinuities, marshy ground and waterlogged areas, etc.
- Investigation of Subsoil profile and soil characteristics np to the depth of failure plane or up to dense/hard rock strata as per the requirement shall be collected.
- Stabilization of Slope
- Benching: Horizontal benches can be excavated into a slope for most effective protection from steep slope failures as it reduces the height of slope.
- Soil Improvement Techniques
- By Vegetation: It is a bio-engineering method.
- Seeding: Seeding with grasses and legumes reduces surface erosion.
- By Turfing/Sodding
- Construction of Soil Nails and Grillage : In soil nailing, metal bars or rods are driven into soil to strengthen the soil mass. They are attached to concrete facing located at the surface of the structure. It prevents erosion of the surface material surrounding the soil nails but do not provide structural support as such.
- Ground anchors: They provide vertical and lateral support for engineered structures and natural slopes. They are used to tie-back retaining walls to prevent failures due to rotational loading and also to strengthen fissured material like rocks. It is provided according to the length required.
- Rock bolts: Rock bolting is a method of securing or strengthening closely jointed or highly fissured rocks in cut slopes by inserting and firmly anchoring a steel bar in pre drilled holes that range in length from less than one meter to about 12 meters and are attached to some type of facing.
- Cable, wire- mesh, fencing: They are simple, low-cost methods for protecting slope.
- Reinforced earth: Reinforced earth is a construction system made up of frictional backfill material reinforced with flexible strips and covered with facing elements.
- Stream Bank Stabilization: i) Riprap, ii) Gabion wall, iii) Reinforced Concrete wall, iv) Steel bin wall, v) Log cribbing, vi) Grid paver, etc.
- Control Surface Water: Catch water or interceptor drains, side drains and cross-drains
- Regular site investigation and monitoring shall be undertaken.

14.5.3.8 Rolling Stock: Impacts on Environment

- CO_2 emission and Energy consumption,
- Noise: Silver Line train noise is classified as rolling noise, noise from mechanical parts like bogie parts, noise from electrical components like air conditioning and blower motors, contact noise from the pantograph, and aerodynamic noise.
- Ground Vibration
- Impact of the interior materials like asbestos, cryogenic liquid, etc. to human health.

14.5.3.8.1 Mitigation Measures

The Silver Line Rolling stock shall conform to the environmental requirements on EMC. Reduction in CO_2 emissions from Silver Line rail service is proportionate to the reduction in energy consumption. Various methods exist to reduce energy consumption: reduction of power unit energy loss, use of regenerative braking and reduction of running resistance. Eco-driving may be incorporated into timetabling and be coupled with a driving support system for the driver to lessen energy use.

Rolling noise may be reduced through measures applied at wheel/rail interaction level, in the form of wheel dampers. Parts and components should be designed to limit structural noise as much as possible. Aerodynamic noise forms one of the main noise sources, this can be reduced with smoother car body surfaces, using noise dampers, using aerodynamic parts, adding parts assisting smooth air flow especially around car gangways and around bogies, fitting noise insulation panels around pantographs and bogies etc.

Ground vibration depends on track side conditions, infrastructure, axle distribution in a train set and axle load. The most effective measure to tackle this in the case of Rolling Stock is to reduce axle loads. Reduced axle load of 16 Ton of Silver Line will reduce the ground vibration.

All hazardous interior materials like asbestos, cryogenic liquid, etc which has negative impacts to human health shall be avoided.

The Rolling Stock shall be designed considering the prevailing climatic and environmental conditions in the corridor. Typically, in India ambient temperature at 0 to 50 C and humidity at 90% or over is required to reflect the environmental conditions and salty atmospheric conditions during hot seasons as well as concentrations of SO_2 and particulate matters suspended in the atmosphere. Environmental conditions for the equipment on board the coach shall conform to EN 50125 -1.

14.5.3.9 Impacts on Socio-Economic Environment

14.5.3.9.1 Impacts due to Project Location (Land Acquisition and Resettlement)

Development projects generate not only positive impact/ benefits but also cause adverse social impacts as well. Various alternatives have been explored from the beginning of the study for finalization of the alignment. One of the prime criteria for selection of final alignment has been least resettlement impacts particularly, impact on residential structures i.e. bypassing habitations/settlements in the project corridor as far as possible. Even then the adverse impacts of the project cannot be avoided fully.

14.5.3.9.2 Impact during Construction Phase

The implementation of the project will result in loss of land, dismantling of structures sometimes leading to displacement, loss of livelihood, loss of community resources, etc. which are falling within the Right of Way (RoW). The proposed project will affect owners, and persons associated with properties and assets. Majority of the project alignment traverses through greenfield area. A total of 1383 ha land area is required for the project corridor length of 529.450 km. Private land area required for project is 1198 ha, which is 86.62% of the total land area required. Railway land between Tirur and Kasaragodand between Kochuveli and Murukkumpuzha stations of S. Railway area required for the project is 185 ha. Major portion of private land will comprise of productive agriculture land. There will be demolition of some properties also, approximately 10349 numbers of structures/buildings likely to be affected. The land acquisition will have impact on socio-economic conditions of the project affected persons. The impact shall be mitigated and adequately compensated as per prevailing state/central government rules.

14.5.3.9.3 Impact during Operation Phase

No impact is envisaged during the operation phase of the project this issue shall be s ettled and mitigated at the construction phase of the project.

14.5.3.9.4 Mitigation Measures

- A detailed Rehabilitation and Resettlement (R&R) shall be undertaken to ensure that all affected persons are properly identified, and their losses are properly assessed.
- The compensation to project affected persons will be paid in accordance with The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013, (RTFCTLARRA 2013), the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Kerala) Rules.

14.5.4 Environmental Enhancement Measures (EEM)

In addition to the mitigation measures suggested to alleviate the minor negative impacts during construction and operation of the project, some of the measures for improvement of environment are proposed to be undertaken, which are:

14.5.4.1 Landscaping and beautification

Landscaping are provided in the open spaces in the offices, stations, depot, parking areas and along the corridors to reduce pollution, enhance aesthetic view and positive effect on the surrounding environment.

14.5.4.2 Renewable Energy

Installation of solar panels is proposed along the corridor, rooftop of all stations and depots etc. It is planned to use 100 % of power from renewable sources like solar by in-house production, purchase of renewable power from third party and KSEBL to make the project as a Green and Sustainable Transport System.

14.5.4.3 Green Building

Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s lifecycle from siting to design, construction, operation, maintenance, renovation and deconstruction.

In view of the above concept, all station buildings, depot, administrative building and other service buildings are designed based on the standard of Indian Green Building Council (IGBC).

14.5.4.4 Rainwater harvesting

The rainwater harvesting will be provided at all stations and depots and other offices for the augmentation of groundwater.

14.5.4.5 Rejuvenation of Abandoned Paddy Fields

Paddy fields are considered to be the air coolers of Earth, reducing the Carbon-Dioxide in the atmosphere and store it in the form of Carbon. Paddy fields thus helps to preserve Earth from hazards of Carbon-Dioxide.

In view of the importance of paddy cultivation, Government of Kerala also have launched a program for Reviving of Paddy Field Forming duly allocating a separate fund and set up a separate executing organization. K- Rail has already associating and coordinating with this program. Necessary assistance of this agency and the special fund can also be taken to revive the damages to paddy fields and convert the follow land (due to the construction of this project) to green paddy fields.

Out of the total land requirement of 1383 Ha for this project, the paddy field land used is 253.45 Ha, which is only 18.3%. Out of 253.45 Ha of paddy land used, approximately

30 Ha will be redeveloped and reclaimed as paddy field and in addition approximately 10 Ha of follow land will be converted as paddy field.

To protect the environment, over large continuous stretch of the paddy fields (At 52.9 to 55.0 km, 91.8 to 94.6 km, 240 to 245 km, and 295 to 298 km) under cultivation, viaduct of approx. 14 km of total length is proposed, in lieu of embankment.

The 15% of net paddy field agricultural land will come down after the follow land is converted into paddy field at the end of the project.

14.5.4.6 Waste Management

Waste management process and machinery is indeed a part of the Silver line project. The maintenance of Rolling Stock and other equipment will generate waste products which are to be treated and disposed properly. Treatment plants are proposed in all Depots for the treatment of the maintenance wastes. Similarly, wastes from the trains are to be collected, treated and disposed properly. Controlled emission plants are used in depot to collect the toilet wastes from the trains and associated treatment plants will treat the waste for proper disposal. In all stations also waste management process are to be implemented. The collected waste from stations are to be treated and disposed either in central facility or local facilities.

Construction wastes generated in the project shall be segregated, recycled and reused in the maximum extent. Construction & Demolition wastes shall be managed as per C&D Waste Management Rules, 2016.

14.5.4.7 Vermicomposting

Vermicomposting facilities will be provided at all satellite offices to treat the kitchen waste as an initiative towards management of Biodegradable waste at site and generate compost for in-house landscaping.

14.5.4.8 Bio Toilets in the Trains

Bio-toilets shall be provided in the trains as a measure of environment protection and cleanliness in the corridor, stations and yards.

14.5.4.9 Electrically Operated Feeder Services

Battery operated buses and rickshaws are proposed to operate in all the stations for connecting the passengers to city centre and main locations near to the stations.

14.5.4.10 Noise and Vibration

For the safeguard of sensitive receptors close to the track from high noise and vibration due to running of trains, protective measures are suggested for which a provision of Rs 50cr is made available.

14.5.5 Summary of Environmental and Social Impact & Mitigation Measures

The environmental impacts and mitigation measures at different phases of the Silver Line project have been described in previous sections. The likely Impact due to the project on the various environmental components is assessed and mitigation measures are derived. The nature of impacts and mitigation measures in the matrix format are presented in Table 14-47.

Table 14-47: Summary of Environmental Impact & Mitigation Measures

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
A: Pre-Construction and Construction Phase				
1	Air Environment	Emission of exhaust gases from construction equipment and vehicles and fugitive dust emission due to earthmoving and construction work; transportation of construction materials; Dust generation at borrow areas; quarrying activities; construction machinery viz., DG sets, Concrete mixers, etc. will cause air pollution in and around the construction sites.	Temporary	Maintain all construction equipment and vehicles to minimize emissions. Regular water spray at dust generation points. Periodic monitoring of ambient air quality as per NAAQS, 2009.
2	Noise & Vibration	Noise and vibration caused by operation of construction vehicles/equipment could annoy the residents and school/hospital nearby. Vibration caused by such construction works may damage the houses and other kinds of building structures such as cracks in the wall/foundation of old buildings /structures.	Temporary	Low noise designed Machinery and vehicles should be used and maintained regularly. No noise generating constructions activities in night-time near residential neighbourhoods. Noise and Vibration monitoring will be undertaken as suggested in the environmental monitoring plan.
3	Water Environment	The deterioration of surface and ground water quality due to drainage of water, wastewater and waste discharges from the camps and construction sites. Muddy water from construction sites and	Temporary	No liquid shall be discharged from any camps and construction site/activity without treatment. No storage of construction material near water courses.

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
		oil spill from construction equipment and vehicles could cause water pollution in the channel/river in and around the construction sites.		Waste from construction camp/site will be disposed off at identified dump sites.
4	Land Environment	Construction works along the river/channel sections could cause soil erosion. Uncontrolled disposal of domestic solid waste and sewage from construction camps and disposal of liquid waste (vehicle/equipment washing effluent) from construction sites can result in land pollution. In case of leakage of lube oil/HSD from the construction yard can lead to deterioration of soil quality/loss of productive soil.	Temporary	Temporary drainage channels will be provided to minimize soil erosion. Construction work may be avoided during rainy season. Waste management system will be adopted in construction camps/sites. Septic tank with soak pit facility will be provide in labour camps to prevent any soil contamination.
5	Flora	Removal of trees growing within the RoW (on both private and public lands)	Permanent	Compensatory plantation using suitable native species or pollution tolerant species should be initiated. For trees to be felled in private land, compensation for trees based on fruit yield value, timber value and other economic value should be given to the owners.
6	Fauna	No major potential impact anticipated as the alignment is not passing through any wildlife park/sanctuary. Removal of trees along the proposed alignment route will lead to the destruction of faunal habitats such as bird nests, breeding sites, etc. Increased sediment loads into water bodies during Viaduct/bridge construction work may impact aquatic fauna.	Temporary	Compensatory afforestation work using suitable native plant species will be undertaken. Suitable engineering control measures shall be applied during bridge construction work to control the sediment loads into water bodies.
7	Hydrology	The project is a linear one/ crossing all the west flowing rivers, streams and agriculture fields/ flood plains are crossed or runs along. Embankments cause	Permanent	High Flood water discharge VENT has to be provided for Bridges/Viaducts. Suitable Irrigation canal crossing structures shall be designed.

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
		Inundation/ obstruct easy flow downstream, increase silt flow, etc.		In Kollam and Kasaragod (station/yard) thodu is running close and parallel and discharging flood waters from its catchment area, suitable protective measures shall be undertaken to divert the flood and to provide flood plain for the natural process of filling and draining. Banking shall be with adequate cross drainage to avoid water logging/flood risk.
Social Environment				
8	Impacts due to Project Location (Land Acquisition and Resettlement)	Private land area required for the Silverline project is 1198 ha and approximately 10349 numbers of structures/buildings likely to be affected. The proposed project will affect owners, and persons associated with properties and assets result in loss of land, dismantling of structures, displacement of people, loss of livelihood, loss of community resources, etc.	Permanent	The impact shall be mitigated and adequately compensated in accordance with The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013, (RTFCTLARRA 2013), the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Kerala) Rules. A detailed Resettlement Action Plans will be prepared separately.
9	Creation of employment opportunities	Positive Impact	Temporary	--
10	Increased trade with construction workers	Positive Impact	Temporary	--

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
11	Business opportunities in supply of materials and utilities	Positive Impact	Temporary	--
12	Less Land Requirement	Positive Impact	Temporary	--
B: During Operation Phase				
1	Air Environment	No major adverse impact on air quality is envisaged in the operation phase. Positive impact on air quality as vehicular traffic will decrease as people will opt for Silverline rail. Air emissions from DG sets at stations and depots in the event of power failure.	Positive Impact	DG sets stack heights and emissions will conform to CPCB stipulated norms.
2	Noise & Vibration	An introduction of the Silver Line Rail substantially reduces the vehicular traffic, which ultimately reduces noise level. Noise and vibration levels may be increased in project influence area.	Permanent	Noise barriers should be erected at appropriate locations such as residential areas and sensitive receptors which are adjacent to the corridor.
3	Water Environment	No impact during operation phase. The cleaning water generated by the washing of the trains and domestic type wastewater generated at the stations will be treated according to the relevant national legislation.	None	No Mitigation measures are warranted.
4	Land Environment	No impact during operation phase.	None	No Mitigation measures are warranted.
5	Flora	Apart from compensatory afforestation work, planned for development of a natural vegetation along the rail corridor, stations and depots which will	Permanent	Positive Impact

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
		assist screening of the railway as well as present an aesthetic view.		
6	Fauna	No impact during operation phase. Impact on aquatic fauna in case of accidental oil spill and toxic chemicals release find its way into the water bodies.	Temporary	Immediate actions should be taken for speedy cleaning up of oil spills, fuel and toxic chemicals in the event of accidents.
7	Hydrology	No adverse impact is envisaged.	None	No Mitigation measures are warranted.
8	Landslides	No adverse impact is envisaged.	Temporary	All suitable preventive/ mitigation measures will be undertaken during construction and regular monitoring will be ensured during the operation phase.
9	Climate Change and Global Warming	The change/shift of transport mode from fossil fuel used automobile to electrified railway system, significant reduction of emissions of greenhouse gas such as CO_2 will be expected per unit transport distance per person.	Permanent	Positive Impact
Social Environment				
10	Impacts due to Project Location (Land Acquisition and Resettlement)	No adverse impact is envisaged.	None	No Mitigation measures are warranted.
11	Local economies, such as employment, livelihood, etc	The regional economy, particularly industrial sectors in major industrial locations is expected to be improved due to smooth fast transportation. Besides, the Silver Line rail project is also expected to create new employment and	Permanent	Positive Impact

Sl. No.	Environmental Attribute	Potential Environmental Impact	Nature of Impact	Mitigation Measures
		business opportunities in the state.		
12	Employment Opportunities	Positive Impact	Permanent	--
13	Improved transport efficiency for people	Positive Impact	Permanent	--
14	Benefits to Economy and social life of the people.	Positive Impact	Permanent	--
15	Reduction of congestion and accidents on Road	Positive Impact	Permanent	--
16	Less Fuel Consumption	Positive Impact	Permanent	--
17	Reduction in air pollution and GHG emission	Positive Impact	Permanent	--
18	Increase Tourism in the State	Positive Impact	Permanent	--
19	Traffic Noise Reduction	Positive Impact	Permanent	--

14.6 ANALYSIS OF ALTERNATIVES

The analysis of alternatives is an effective tool to examine the number of options (locational & technological) and establishing most environmentally favourable alternatives or which cause minimum environmental loss to the natural and social environment. Analysis of Alternatives and selection of an alignment is a multidisciplinary decision, with objectives which may conflict with one another. The selection of approach for resolving the problem is the multi- criteria analysis for the alternative to be analyzed. The principal objectives which were consider while selecting alignment of Silver Line semi high speed rail corridor are minimization of the impact on the environment & social, minimum land acquisition, optimization of the functionality of the alignment, minimization of construction time, minimization of construction and operational cost and maximization of the results of the economic investment. Technical parameters, construction feasibility, minimization of construction time, construction and operational cost, traffic and advantages to people are amongst the criteria with the highest weighting factors in selecting the optimal alignment.

14.6.1 With or Without Project Scenario

The ‘with’ or ‘without’ project scenarios are a major consideration of the cost-benefit analysis of a project. Providing better and faster connectivity across the State will ensure that goods and people can move in and out of the areas more efficiently. The project is expected to spin off increased trade and commerce activity throughout the State as the project has been designed to connect the various urban economic growth centres within the state. Without this project, it is expected that there will be an increase in air pollution, due to slow moving traffic and congestion. Travel will take longer thus impacting productivity and reducing the economic growth of the area. Overloading of existing transport infrastructure will also affect safety and lead to loss of human life due to increase in accidents.

14.6.2 Alternative Scenarios for Silver line

The potential alignments for the Silver Line Semi High Speed Rai Corridor, initially identified by the study brief, were as follows:

Alternative 1 - Alignment in New Areas and Along the Existing Rail

In this option, the alignment has been split into two segments as under:

- Thiruvananthapuram to Tirur through new areas
- Tirur to Kasaragod along the existing rail

Alternative 2 - Alignment Along the Existing Rail

In this option, the possibility of providing an alignment parallel to the existing rail corridor was studied. The alignment runs along the existing rail corridor following the sharp curves, it is not possible to get the desired speed of 200 kmph due to speed restriction at several places which will defeat the purpose of the Semi High Speed Corridor planned.

Alternative 3- Silver line with Viaducts and Bridges/ tunnels

Alignment runs on viaduct/ bridges/ tunnels minimizing the footprint area and avoiding all the land related issues with minimal land acquisition for construction of pillars and tunnels. However, the cost of construction is almost double as compared to Alternative 2 and 3.

Alternative 4 - No Silver line - Business-as-Usual

In the absence of Silver line, the passenger travel choices will continue to operate on the existing modes including road, rail and air. In addition, growing ownership of private vehicles will result in significant number of trips being served by cars. Road are predicted to continue to dominate, especially short trips between intermediate cities along the Silver line corridor. Thus, there may be an increase in private vehicles at the expense of public transport like Rail, which shall have serious effect on the GHG emissions.

Alternative 5 – Express Highway

Construction of a new express highway requires more land acquisition and may have high social and environmental impacts. The land requirement for construction of Express highway to cater same amount of traffic is 3 times more.

Table 14-48: The comprehensive comparison of five alternatives

Parameters	Alternative 1 - Alignment in New Areas and Along the Existing Rail	Alternative 2 - Alignment Along the Existing Rail	Alternative 3- Silver line with Viaducts and Bridges/ tunnels	Alternative 4 - No Silver line - Business-as-Usual	Alternative 5 – Express Highway
Land use	The footprint area of this alternative is low; uses ~2.8 ha/ km.	The footprint area is higher than Alternative-1 due to length, close vicinity of the railway line and existing structures	More efficient on land use; uses ~2.4 ha/km.	For widening of road, 6.1 ha/ km land need to be acquired	Land requirement to cater same amount of traffic is 3 times more
Travel Time	Time savings from Silver line are significant. 4 h between Thiruvananthapuram and Kasaragod	More than 5 h between Thiruvananthapuram and Kasaragod due to speed restriction at many places	4 h between Thiruvananthapuram and Kasaragod	More time due to slow speed. 10 to 12 h depending upon the speed	More time due to slow speed. 6 to 8 h depending upon the speed
GHG Emissions	Due to higher energy efficiency, net GHG emissions are expected to be lower. Annual average emissions	GHG emissions lower. Annual average emissions reduction of about 2,87,994 Tonnes CO_2e/year	GHG emissions lower. Annual average emissions reduction of about 2,87,994 Tonnes CO2e/year	GHG emission estimated to be 31,20,328 Tonnes CO_2e/year	GHG emission estimated to be 31,20,328 Tonnes CO_2e/year

Parameters	Alternative 1 - Alignment in New Areas and Along the Existing Rail	Alternative 2 - Alignment Along the Existing Rail	Alternative 3- Silver line with Viaducts and Bridges/ tunnels	Alternative 4 - No Silver line - Business-as-Usual	Alternative 5 – Express Highway
	reduction of about 2,87,994 Tonnes CO_2e/year				
Fuel Consumption	Significant reduction in fuel consumption	Significant reduction in fuel consumption	Significant reduction in fuel consumption	Higher fuel consumption	Higher fuel consumption
Safety	High safety and efficiency kept	High safety and efficiency kept	High safety and efficiency kept	Low safety and efficiency kept	Moderate safety & efficiency kept
Cost	Length of corridor is less (529.450 km) to economise the cost.	Length of corridor is 577 km. Cost is higher than Alternative – 1 due to dense habitation in the area.	Cost almost double	High cost	High Cost
Environmental & Social Aspects	Low impact on environment. Overall economical & will have less cost of construction. **This is the most desirable plan**	High impact on social environment and speed restriction due to sharp curves. This plan is not technically feasible, inferior to ALT1.	Low impact on environment. This plan is inferior to ALT1 and ALT2.	High impact on environment. This plan is inferior to ALT1, ALT2 and ALT3.	High impact on environment. This plan is inferior to ALT1, ALT2, ALT3 and ALT4.

14.7 ENVIRONMENT MANAGEMENT PLAN

The Environment Management Plan (EMP) provides guidance on how the project activities are to be planned, implemented and monitored in order to minimize and manage environmental and social impacts. EMP has been developed based on the assessment of potential impacts of the project based on the review of secondary information, substantiated by field surveys and measurements, public consultation, household surveys and discussions with concerned authorities. EMP outlines the mitigation, monitoring and institutional measures to be taken during project implementation and operation to avoid, minimise or mitigate adverse environmental impacts and the actions needed to implement these measures. The generic environmental parameters that need to be monitored during pre-construction,

construction and operation phases of the project are summarized in Tables 14-49, Table 14-50 and Table 14-51 respectively.

Table 14-49: Environmental Management Plan for Pre-Construction Stage

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
1	Land acquisition and Resettlement	The acquisition of land should be carried out in accordance with the RAP	Parties should be determined in a separate RAP Study	K-Rail
2	Consents, permits, clearances, no objection certificate (NOC), etc.	All the applicable consents, permits, clearances, NOCs, etc. shall be obtained before the commencement of the construction work	Design Consultant and K-RAIL	K-Rail
3	Tree / Mangrove Cutting & Afforestation	Avoidance of non-essential tree cutting Planting of native tree species should be taken up Green belt development at the sensitive locations along the alignment Compensatory Mangrove Afforestation should be taken up	Design Consultant and Contractor	K-Rail
4	Crushers & Concrete Batching Plants	All construction yards should be sited at least 500m away from settlements Arrangements to control dust pollution through provision of wind screens, water sprinklers, and dust suppressant and extraction systems should be provided at all such sites Specifications for crushers, and concrete batching plants should be designed to comply with the requirements of the relevant emission control legislation at the State level Consent for the establishment and operation from Kerala State	Design Consultant and Contractor	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		Pollution Control Board should be obtained before establishment and operation of work sites		
5	Construction camps site, and locations of material storage areas, sanitation facilities	The construction camps should be located at least 200m away from habitations at identified sites near alignment Location for stockyards of construction materials should be identified at least 500 m away from water bodies The sewage and solid waste treatment and management for the camp should be designed, built and operated All sites used for camps should be adequately drained The labour camp/construction camp should be established as per the provision of Occupational Safety and Health Administration	Design Consultant and Contractor	K-Rail
6	Sources of construction materials	Use quarry sites and sources licensed by the Kerala Government	Design Consultant and Contractor	K-Rail
7	Construction Vehicles, Equipment &Machinery	All equipment and machinery used for construction should conform to the relevant Bureau of India Standard (BIS) norms The discharge standards promulgated under the Environment Protection Act, 1986 and Motor Vehicles Act, 1988 should be considered while procuring vehicles The silent/quiet equipment should be preferred	Design Consultant and Contractor	K-Rail
8	Construction Water	Surface / Ground water for construction requires necessary permissions which should be obtained from the respective State	Design Consultant and Contractor	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		Irrigation Department, KWA and CGWA		
9	Quarry Areas	Procurement of construction materials from quarries should be finalized after assessment of the availability of sufficient materials, quality, regulatory and other logistic arrangements Necessary clearances should be obtained for the locations selected from the statutory agencies like the KSPCB and from the Mining Department Planning of haul roads for accessing quarry areas should be undertaken during this stage The sand should be procured from identified sand mines	Design Consultant and Contractor	K-Rail
10	Borrow Areas	The earth material is to be borrowed from select borrow areas, until the formal agreement is signed between landowner and the executing agency Planning of haul roads for accessing borrow areas should be undertaken during this stage Locations finalized, and the necessary clearances should be obtained from the statutory agencies like the KSPCB and from the Mining Department	Design Consultant and Contractor	K-Rail
11	Labour Health &Safety	Develop comprehensive site-specific health and safety (H&S) plan. Provisions for health care facilities and Regular health check-up of the deployed workforce should be undertaken	Design Consultant and Contractor	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
12	Disaster	Adequate cross drainage channels (longitudinal and median drains) should be provided along the route at suitable locations for the smooth passage of the surface run-off to prevent flooding	Design Consultant and Contractor	K-Rail
13	Ethnic Community and Indigenous People	The right and interest of the ethnic community and indigenous people should be protected	Design Consultant and Contractor	K-Rail
14	Cultural and Religious site	Pier spacing should be adjusted to avoid the demolition of the religious structures falling within RoW However, if it is unavoidable, every step should be taken to shift these structures at a suitable place in consultation with the local community Effective noise barriers/screens should be provided close to working heavy equipment	Design Consultant and Contractor	K-Rail
15	Public consultations	Continue information dissemination, consultations, and involvement/ participation of stakeholders during project implementation	Design Consultant and Contractor	K-Rail

Table 14-50: Environmental Management Plan for Construction Phase

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
1	Clearing and uprooting of Vegetation	If required, vegetation should be removed from the construction zone before commencement of construction after obtaining necessary permissions All works should be carried out such that the damage or disruption to flora other than in those areas identified for cutting is kept to a bare minimum	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
2	Drinking water availability	Sufficient supply of cold potable water to be provided and maintained	Contractor	Consultant and K-Rail
3	Stockpiling of construction materials	Stockpiling of construction materials does not impact, obstruct the drainage Stockpiles should be covered to protect from dust and erosion	Contractor	Consultant and K-Rail
4	Transporting Construction materials and haul road management -.	Dumpers and trucks carrying the construction material should be spill proof Trucks and dumpers should be properly maintained Water should be sprinkled on the haulage roads Strict speed limits should be followed at the settlement areas and on the haulage roads All the truck and dumper drivers should be properly trained.	Contractor	Consultant and K-Rail
5	Borrow areas and quarry sites	Borrow areas and quarry sites should be away from human settlements The excavation of borrow should be specified as per the guidelines. Access to the quarry operated area and borrow sites should be strictly controlled All workers at the quarry site should be provided with personal protective equipment All the haul roads are watered regularly to reduce dust emissions A vegetative barrier should be created to surround the borrow area	Contractor	Consultant and K-Rail
6	Disposal of debris from dismantling structures	The construction and demolition waste generated should be managed in accordance with the C&D Waste Management Rules, 2016	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
7	Traffic diversions and detours	The temporary traffic detours should be kept free of dust by sprinkling water during the daytime depending on weather conditions	Contractor	Consultant and K-Rail
8	Construction water arrangements	Water required for construction should be drawn from surface waterbodies with prior permission from LSGDs If ground water is drawn, then permission from the CGWA or State GWD should be obtained	Contractor	Consultant and K-Rail
9	Waste Management	Avoid uncontrolled solid waste dumping which could be breeding ground for vermin, and as such could pose a vector for disease Segregation of waste depending on the nature of the materials should be carried out Special attention should be given to diverting hazardous materials/wastes for proper management in accordance with applicable regulatory requirements The prevailing rules and act MSW Act, 2016 should be strictly adhered to	Contractor	Consultant and K-Rail
10	Waste water generation from construction yard and labour camps	The wastewater from construction yard and labour camp should be treated (as per applicable discharge standards) before being discharged	Contractor	Consultant and K-Rail
11	Siltation in waterbodies	Construct silt fencing at the base of the embankment construction site and around the stockpiles The fencing should be provided prior to commencement of earth work and continue until the stabilization of the embankment slopes Construction materials containing fine particles should be stored in an enclosure	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		If necessary, siltation pond shall be installed to avoid discharging silt water from the site		
12	Energy Management	Should use energy efficient lighting, motors and pumps Adequate and uniform illumination level at construction sites suitable for the task Proper size and length of cables and wires to match the rating of equipment Camps should be designed for maximum daylight and minimum heat gain.	Contractor	Consultant and K-Rail
13	Slope protection and control of soil erosion	Soil erosion and sedimentation should be minimized by constructing breast walls, retaining walls, pilot bioengineering methods, dykes, sedimentation chambers, basins, fibre mats, mulches, grasses, slope, drains and other such devices	Contractor	Consultant and K-Rail
14	Petroleum Oil and Lubricants	POL should be handled with special care with necessary permissions The used oil and lubricants should be sold to authorized parties The storage places for POL should have restricted entry Accidental spillage of oil and lubricant should be immediately cleared The trucks and dumpers will not be washed at the nearby water bodies	Contractor	Consultant and K-Rail
15	Public Health and Safety	The general public/local residents shall not be allowed in high-risk areas, *e.g.*, excavation sites and areas where heavy equipment is in operation Speed restrictions should be imposed on deployed vehicles &equipment when traversing areas with sensitive receptors. Marshalling attendants should be provided at traffic junctions outside	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		construction yard sites to regulate material / construction vehicles and general vehicular traffic / pedestrians in a safe manner Traffic diversion plans should be prepared/ executed and communicated in areas where construction is being carried out on or near existing roads/ highways in consultation with local traffic police		
16	Construction Yards	Site construction yards should minimize adverse impacts by good management practices Implement malaria control, HIV/AIDS education Plan and carry out post construction site clean-up	Contractor	Consultant and K-Rail
17	Air Pollution	Water sprinkling system should be put in place Covering the construction material/waste during transportation to/from the construction site should be considered to reduce diffusion of dust Equipment & trucks should be properly maintained at regular intervals No excavation of soil should be carried out without adequate dust mitigation measures in place Grinding and cutting of building materials in open area should be prohibited Motorized vehicles at site should be restricted to a max speed of 20 km/hr Wheel washing facility at exit of construction sites should be provided	Contractor	Consultant and K-Rail
18	Noise Pollution	Construction activities generating high noise levels should be carried out at different time intervals during day time The equipment used should have exhaust mufflers	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		All equipment should be properly lubricated. The construction yards located near sensitive receptors should be provided with noise barriers Periodical inspection and effective maintenance of vehicle and equipment		
19	Installation and Operation /Maintenance of Electrical Equipment	All necessary fencing & lights should be provided to protect the public in construction zones All machines to be used in the construction should be kept in good working order, and should be regularly inspected and properlymaintained16	Contractor	Consultant and K-Rail
20	Establishment and Operation of the Labour Camps	The labour camps should be provided with adequate treatment system and drainage to avoid accumulation of stagnant wastewater Toilets/sanitation facilities with proper flushing provisions in accordance with local regulations to prevent any hazard to public health or contamination of land, surface or groundwater. These facilities should be well maintained to allow effective operation. Fire-extinguishing equipment should be provided at construction camps, asphalt plants, storage areas for combustible materials and other areas where fire hazards are found. All site workers should be provided with personal protective equipment such as safety shoes, helmets, earmuff, nose mask as relevant to the risks that they are exposed to *etc*.	Contractor	Consultant and K-Rail
21	Clearing of Construction of Camps and Restoration	On completion of the works, all temporary structures will be cleared away, all rubbish burnt, excreta or other disposal pits or trenches filled in and	Contractor	Consultant and K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		effectively sealed off and the site left clean and tidy		

Table 14-51: Environmental Management Plan for Operation Phase

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
1	Noise	Noise generated from operation of DG set to be optimized and monitored DG sets to generate less than 75 dB(A) Leq at 1-m from the source DG sets are to be provided at basement with acoustic enclosures Periodical inspection and effective maintenance of vehicle and equipment Noise barriers should be erected at appropriate locations such as residential areas and sensitive receptors, which are adjacent to the corridor.	Consultant	K-Rail
2	Vibration	The vibrations can be reduced considerably by ensuring and keeping correct track geometry by advanced measurement. The track structure should be designed to produce low ground-borne vibration Controlling noise and vibrations at the source, e.g. track measures like rail grinding, welding to smooth discontinuity, lubrication, use of soft rail pads and relocation of signals or turnouts The other mitigation measures include wheel lubrication, use of disc brakes, dampening of wheel and use of resilient wheels Avoid vibratory rollers and packers near sensitive areas	Consultant	K-Rail
3	Indoor air contamination	Pollutants such as CO, CO_2 and VOCs to be reduced as per CPCB/ KSPCB	Consultant	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		guidelines by providing adequate ventilation		
4	Drinking water availability	Sufficient supply of cold potable water to be provided and maintained at stations& depot areas	Consultant	K-Rail
5	Water Quality and Water Levels	Monitoring groundwater quality and levels should be carried out around station and depot areas	Consultant	K-Rail
6	Waste Management	Avoid uncontrolled solid waste dumping which could be breeding ground for vermin, and as such could pose a vector for disease Segregation of waste depending on the nature of the materials should be carried out Special attention should be given to diverting hazardous materials/wastes for proper management in accordance with applicable regulatory requirements The prevailing rules and act MSW Act, 2016 should be strictly adhered to	Consultant	K-Rail
7	Wastewater Discharge	No untreated discharge to be made to surface water, groundwater or soil. The cleaning water shall be collected in tanks and disposed only after proper treatments as per CPCB guidelines	Consultant	K-Rail
8	Drainage and effluent Management	Ensure drainage system and specific design measures are working effectively. Design to incorporate existing drainage pattern and avoid disturbing the same	Consultant	K-Rail
9	Maintenance Performance	Monitoring of the operational performance of the various mitigation/enhancement measures should be carried out as a part of the project. The indicators selected for monitoring include the survival rate of trees; utility of enhancement provision for relocated	Consultant	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
		utilities, hand pumps and other relocated structures if any; status of rehabilitation of borrow areas; and noise barriers, which are proposed at different locations.		
10	Borrow areas and quarry sites	Incorporate adequate drainage and fill in borrow pits and quarries Maintain borrow pits and quarries by landscaping them after operation by growing native species The guidelines issued by the State Mines and Geology Department should be followed	Consultant	K-Rail
11	Green belt Development and Management	Maintenance of plantation Local pollutants tolerant species should be selected for plantation	Consultant	K-Rail
12	Training for operational staff	The training should be for all the executives regarding the environment and safety The process should be followed for a minimum period for first six months	Consultant	K-Rail
13	Emergency Preparedness and Response Management	Maintenance of cross drainage channels (longitudinal and median drains) should be carried out. The rolling stock and stations should be provided with the alarm for advance notice of earthquake, cyclone, flood *etc.* Risk & Disaster Management Plan should be formulated for safe &smooth running of the Silver Line train	Consultant	K-Rail
14	Maintenance Depots and Yards	The two major maintenance depots have been proposed The depots shall function in accordance with the provision of the Factory Act, 1948 and State level Factories Rules, as applicable	Consultant	K-Rail

Sl. No.	Parameters/ Components	Mitigation Measures	Responsibility	
			Implementation	Supervision
15	Energy Management	Use of energy efficient lighting, and other products Proper size and length of cables and wires to match the rating of equipment Use of energy efficient air conditioners Stations should be designed for maximum daylight and minimum heat gain. The rooms should be well insulated to enhance the efficiency of air conditioners and the use of solar films on windows may be used where feasible	Consultant	K-Rail

14.8 ENVIRONMENT MONITORING PROGRAMME

An Environmental Monitoring Programme (EMoP) normally involves following two main types of activities, viz., i) Routine Supervision of the Work: Observation of the construction/operation work to ensure mitigation actions will be conducted during routine site inspections. This work will be conducted as general operation working/maintenance progress including daily work; ii) Environmental and Social Impact/Mitigation Monitoring*:* The monitoring to be conducted to determine the actual and social impact. Table 14-52 and Table 14-53 shows the EMoP for the construction stage and operation stage.

Table 14-52: Environmental Monitoring Programme for Construction Stage

Sl. No.	Environmental Indicator	Method/ Parameters	Location, Quantity and Frequency	Responsible Agency
1	Air quality monitoring	SO_2, NOx, CO, PM_{10}, and $PM_{2.5}$	10 Locations at Station area and other sensitive locations for 3 times in a year (once in every season except monsoon) or as per CPCB/KSPCB requirement for 5 years	Contractor/Consultant
2	Surface Water quality monitoring		1 sample of 12 major water bodies, 12 times/year for 5 years	Contractor/Consultant
3	Ground Water quality monitoring		Major habitation areas along alignment (12locations), 12 times / year for 5 years	Contractor/Consultant

Sl. No.	Environmental Indicator	Method/ Parameters	Location, Quantity and Frequency	Responsible Agency
4	Soil Quality		16 locations (at stations &depots etc.), 4 times/ year for 5 years	Contractor/Consultant
5	Monitoring of Embankment Drainage		20critical locations (including stations & depots etc.), 2 times/year for 5 years	Contractor/Consultant
6	Waste Management		Construction site as required	Contractor/Consultant
7	Noise Monitoring		22 locations (at stations, depots and other sensitive area), 4 times/year for 5 years	Contractor/Consultant
8	Vibration Monitoring		16 locations (at stations, depots and other sensitive area), 4 times/year for 5 years	Contractor/Consultant
9	Biota and ecosystem	Monitoring whether impacts to ecosystem	Construction site as required	Contractor/Consultant
10	Land Contamination monitoring	Check the maintenance of construction machine	Construction site as required	Contractor/Consultant
11	Occupational Health Monitoring	Opinion or complaint of construction worker	Construction site 4 sessions / year for 5 years	Contractor/Consultant
12	Involuntary resettlement, Poor		Whole through construction stage	Consultant
13	Social Aspects	Opinion or complaint of residents near the construction site	Construction site as required	Contractor/Consultant
14	Misdistribution of benefits and damages	Opinion or complaint of residents	Construction site as required	Contractor/Consultant

Sl. No.	Environmental Indicator	Method/ Parameters	Location, Quantity and Frequency	Responsible Agency
		near the construction site		
15	Local conflicts of interest	Opinion or complaint of residents	Construction site as required	Contractor/Consultant

Table 14-53: Environmental Monitoring Programme for Operation Stage

Sl. No.	Environmental Indicator	Method/ Parameters	Location, Quantity and Frequency	Responsible Agency
1	Air quality monitoring	SO_2, NOx, CO, PM10, and PM 2.5	10 Locations at Station area and other sensitive locations for 3 times in a year (once in every season except monsoon) or as per CPCB/KSPCB requirement for 3 years	Contractor/Consultant
2	Surface Water quality monitoring	pH, SS, Temperature, Oil and Grease, Coliform bacteria	1 sample of 12 major water bodies, 12 times/year for 3 years	Contractor/Consultant
3	Ground Water quality monitoring	pH, SS, Temperature, Oil and Grease, Coliform bacteria	Major habitation areas along alignment (12 locations), 12 times / year for 3 years	Contractor/Consultant
4	Soil Quality		16 locations (at stations and depots etc.), 4 times/y for 3 years	Contractor/Consultant
5	Monitoring of Embankment Drainage		20 critical locations (including stations and depots etc.), 2 times/year for 3 years	Contractor/Consultant
6	Waste Management	Inventory record of waste disposal	Every stations and Depot	Contractor/Consultant
7	Noise Monitoring	Day and Night (L10, L50, L90, LMax, LMin Leq LDay, LNight)	22 locations (at stations, depots and other sensitive area), 2 times/year for 3 years	Contractor/Consultant

Sl. No.	Environmental Indicator	Method/ Parameters	Location, Quantity and Frequency	Responsible Agency
8	Vibration Monitoring		16 locations (at stations, depots and other sensitive area), 2 times/year for 3 years	Contractor/Consultant
9	Biota and ecosystem	Monitoring the impacts to ecosystem &trees planted	Arbitrarily around the planned route& Site of Trees Planted	Contractor/Consultant
10	Restoration of Livelihood		1st monitoring: within 6 months after resettlement is completed 2nd monitoring: within 12 months from 1st monitoring 3rd monitoring: within 24 months from 1st monitoring	External monitoring consultant
11	Social Institutions		1st monitoring: within 6 months after resettlement is completed 2nd monitoring: within 12 months from 1st monitoring 3rd monitoring: within 24 months from 1st monitoring	External monitoring consultant
12	Indigenous or ethnic minority	Monitoring by external monitoring agency	1st monitoring: within 6 months after resettlement is completed 2nd monitoring: within 12 months from 1st monitoring 3rd monitoring: within 24 months from 1st monitoring	External monitoring consultant

14.9 COST FOR IMPLEMENTATION OF EMP AND EMoP

The EMP and EMoP should be implemented by the Construction Contractor or Consultant. The budgetary provision for implementation of the EMP, EMoP and Cost of land and R&R are detailed in Table 14-54, Table 14-55, Table 14-56 and Table 14-57. For costs estimation for implementation of the EMP and EMoP, the total construction period has been considered as 5 years (60 months) and for the operation phase, a period of 3 years has been taken into account.

Table 14-54: Budgetary Provision for EMP and Environmental Protection Measures

Sl. No.	Item	Unit	Unit Cost (INR)	Quantity	Total Cost (INR in Crore)
1	Compensation for tree cutting	Number	5000	15000	7.5
2	Compensatory Afforestation Programs & Maintenance	Number	2000	75,000	15
3	Mangrove Cutting	Ha	200000	2 ha	0.04
4	Compensatory Mangrove plantation & Maintenance	Ha	600000	10 ha	0.6
5	Noise & Vibration barrier construction at Identified Sensitive Locations	m^2	30000	50000	150
6	Maintain borrow pit site by landscaping and re-vegetating after operation	Site	500000	10	0.5
7	Maintain quarry site by landscaping and re-vegetating after operation	Site	300000	20	0.6
8	Water Sprinkling on the road, especially in/near the settlement areas	Monthly	1200000	60	7.2
9	Solid and Liquid Waste Management	Site	2000000	12	2.4
10	Post construction clean-up to ensure no dangerous debris are left behind the camp	Site	50000	10	0.05
11	Green belt development and Management	Site	500000	20	1
Total					**184.89**

Table 14-55: Costs for implementation of EMoP for Construction Phase

Sl. No.	Monitoring Item	Unit	Unit Cost (INR)	Quantity	Total Cost (INR in Crore)
1	Air quality monitoring	No. of Sample	7500	330	0.248
2	Surface Water quality monitoring	No. of Sample	5000	720	0.36
3	Ground Water quality monitoring	No. of Sample	5000	720	0.36
4	Soil Quality	No. of Sample	6000	256	0.154
5	Monitoring of Embankment Drainage	Location	15000	200	0.3
6	Waste Management	Lump sum	2400000	1	0.24
7	Noise Monitoring	No. of Sample	5000	440	0.22
8	Vibration Monitoring	No. of Sample	20000	320	0.64
9	Biota and ecosystem	Lump sum	2400000	1	0.24
10	Land Contamination Monitoring	Lump sum	1600000	1	0.16
11	Occupational Health Monitoring	Session	100000	20	0.2
12	Involuntary resettlement, Poor	Lump sum			5.0
13	Social Aspects	Lump sum	1200000	1	0.12
14	Misdistribution of benefits and damages	Lump sum	1200000	1	0.12
15	Local conflicts of interest	Lump sum	1200000	1	0.12
Total					**8.482**

Table 14-56: Costs for implementation of EMoP for Operation Stage

Sl. No.	Monitoring Item	Unit	Unit Cost (INR)	Quantity	Total Cost (INR in Crore)
1	Air quality monitoring	No. of Sample	7500	240	0.18
2	Surface Water quality monitoring	No. of Sample	5000	432	0.216
3	Ground Water quality monitoring	No. of Sample	5000	432	0.216
4	Soil Quality	No. of Sample	6000	192	0.115
5	Monitoring of Embankment Drainage	Location	15000	120	0.18
6	Waste Management	Lump sum	1800000	1	0.18
7	Noise Monitoring	No. of Sample	5000	132	0.066
8	Vibration Monitoring	No. of Sample	20000	96	0.192
9	Biota and ecosystem	Lump sum	1800000	1	0.18
10	Restoration of Livelihood	Lump sum	1200000	1	0.12
11	Social Institutions	Session	100000	16	0.16
12	Indigenous or ethnic minority	Lump sum	1200000	1	0.12
Total					**1.5902**

Table 14-57: Cost of Land and R&R

Sl. No.	Item	Total Cost (INR in Crore)
	Land	
1	Private land	6100.3
2	Government land	0
3	Railway land 185 Hectares	975
4	Cost for compensation of structure	4460
5	Cost of R&R	1730
	Total	**13265.3**

14.10 CONCLUSIONS AND SUMMARY

In order to provide improved mobility to increasing population of Kerala, number of tourists and trade needs in coming years, (constrained by a non-commensurate expansion of existing road and rail network), K-Rail proposes to develop Silver Line Rail Corridor right from Thiruvananthapuram to Kasaragod, covering almost the entire State. The Silver Line route covers 11 districts out of total 14 districts, and more than 85% of the population of the State.

Based on the analysis of available data and other inputs for the route and data collected during field visit and relevant literature review, the Environmental and Social Impact study is summarised here.

Sub Chapter 14.1 on introduction provides details of Kerala State, highlighting the need for Silver Line project in the state.

Sub Chapter 14.2 provides salient features of Silver Line rail corridor project along with details of Silver Line rail route, stations & depot and land requirement for execution of project has been presented. Silver Line shall operate between Thiruvananthapuram and Kasaragod (529.450 km) with total 11 stations in-between. This will cover more that 85% population of the Kerala State. Total land requirement has been estimated to be about 1383 ha, including the land required for stations and depot. Civil engineering aspects/construction details are also provided along with the train operation plan. Train will run at a commercial speed of about 200 kmph and total travel time from Thiruvananthapuram to Kasaragod will be about 4 hours (including stoppage times at intermediate stations).

Applicable Policy, Legal & Administrative Frame Work in respect to Silver Line rail corridor is presented in sub chapter 14.3.

Since train will cover almost the entire state, geological and hydrogeological features of the whole region/ Kerala state have been presented in Sub Chapter 14.4. Salient features of Kerala with respect to physiography, geology, coastal landforms and soil are presented.

The State‘s geographical location, weather pattern and high population density makes it prone to severe natural as well as human-induced disasters. The State is prone to a host of natural hazards such as coastal erosion, flood, drought, lightening, landslide and earthquake. Almost all districts of Kerala are multi-hazard prone. Since the proposed Silver Line rail corridor route goes along the Kerala Coast, therefore coastal hazards such as cyclone, coastal erosion, tsunami and earthquake are discussed in the chapter.

Sub Chapter 14.4 presents baseline environmental quality and socio-economic status of the Kerala State. Existing status of environmental quality in the region along the proposed Silver Line rail corridor has been assessed through site survey and secondary data available with various Govt. Departments, Research/ Academic

Institutes and published documents/ research papers. Further, data collected/observations made during field visit has been utilized. Environmental quality data has been presented for different components of the environment viz. air, noise, water, biological (terrestrial and aquatic) and socio-economic.

Ambient air quality data monitored at 10 different districts/cities reveal that concentration of major air pollutants like, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO are well within the permissible levels. Air quality index values for different cities of Kerala reveal good to satisfactory status of air quality. Overall, air pollution does not seem to be a serious issue in Kerala, except in some areas, where it could be a highly localized problem.

Ambient noise quality monitored at 22 different locations and the result shows that noise levels at most of the monitored locations are well within the stipulated national standard but some locations exceeding the permissible limit. However, one can expect high noise levels in any area depending upon level of activity taking place and also along the traffic corridor. As such noise is not an issue, however, noise levels should be monitored on regular basis and proper control/mitigation measures should be adopted to keep levels within the permissible levels, particularly during construction phase of the project.

Study of water environment encompasses assessment of surface and ground water quality and quantity available in the study area. There are 44 rivers flowing in the Kerala State. Out of these 44 rivers, 41 of them are flowing westward and 3 are flowing eastward. The total water availability as average annual stream flow is 6,357 MCM/ annum from 34 major and minor rivers. As per the district wise rainfall information available on Indian water portal, Kerala receives an average annual rainfall of 3049 mm. This rainfall partly appears as stream flow and rest of the precipitation contributes in groundwater recharge. Groundwater availability is estimated to be 4087.23 MCM/annum.

The surface water quality of various rivers conforms to CPCB classification - Class C (drinking water source after conventional treatment and disinfection) at most of the locations, w.r.t. pH, DO, BOD and Total coliform. The overall groundwater quality in various districts conforms to the permissible limit of drinking water standards (IS: 10500-2012) at most of the locations.

Land use pattern of Kerala reveals that out of the total geographical area (38864.9 km^2) of the state, as much as 60% area is under agriculture and approx.27% under forest (dense, deciduous, mixed, planted). Water bodies occupy about 3% area.

Classification of land area on the basis of land utilization such as forest, agriculture, barren & uncultivable land, cultivable wasteland, fallow land, marshy land, still water, water logged area, under social forestry, net area sown, area sown more than once, total cropped area etc. has been presented. The data reveal considerable changes in land use pattern in different land use classifications over the decade.

Status of flora & fauna in the State as well as along the Silver Line rail corridor was assessed. The Silver Line corridor is not passing through any reserved or protected forest. There are no threatened or endangered plant species or habitats for such species known to be within the RoW. Details of different types of forests, forest cover, structure and composition of vegetation, rare & endangered flora and medicinal plants are presented. The forests of Kerala are home to some of the endemic and endangered species of India. The forest of the Kerala is about 11310 km², which is 20.1% of the total area of the state. According to the legal policy of the Kerala State Forest Department, it is classified under Reserved Forest, proposed reserve, vested forest and ecological fragile land. The forest types are open shrub type with dominant bushes which are found abundantly in arid zone. Plantation has also been carried by Kerala State Forest Department in many patches. 26 forest types are identified in Kerala (Champion and Seth, 1968) of which the major ones with respect to tree growth are west coast tropical evergreen, west coast semi-evergreen, southern moist mixed deciduous, southern dry mixed deciduous, southern montane wet temperate forests, southern subtropical hill forests, mangrove forests and swamp forests.

The floral diversity of Kerala can be categorized into three (i) Wild and Indigenous, (ii) Indigenous and Cultivated (iii) Exotic, yet cultivated or wild. Wild and indigenous floral elements are found in natural forests and other natural ecosystems. Most of the area which is under the proposed rail corridor is open scrubland and monotoculture of Coconut (Cocos nucifera), Areca nut (Areca catechu), Anjili (Artocarpus hirsutus), Mango (Mangifera indica), Teak (Tectona grandis), Jackfruit (Artocarpus heterophyllus) and other miscellaneous species while in the remaining area is having agriculture crop field with some portions of sparse, short heighted vegetation etc.

Major area surveyed parallel to the corridor in terms of vegetation is devoted to agricultural practices and plantation of the commercial trees like coconut, areca nut, anjili, mango, jackfruit and banana. The forest types are mostly comprising of the tropical forest type while, vegetation is changed near coastal areas. The general floristic composition and physiognomy of vegetation near the human habitation are typically low-level evergreen forest.

Further, status and details of fauna, faunal diversity, mammals, herpeto-fauna, avifauna, insect diversity, critically endangered animal species and domestic fauna/ livestock are presented.

Kerala has a long history of protecting wild animals. There are 6 national parks and 17 wildlife sanctuaries in the state covering 2,67,988 ha area which forms 28.5% of the forest area in the State and 6.4% of the geographical area. The alignment lay out has been very wise as it does not cover any protected areas like National Parks, Wildlife Sanctuary and Biosphere Reserves as per Wildlife Protection Act, 1972 along the both side of the alignment (10 km wider) of the proposed site or proposed station areas. The same has been confirmed by the State Forest Department too. No area or village along the alignment or proposed station falls under Western Ghats Notification, 2015. Hence, no ecologically sensitive areas were observed during our field survey and as per our secondary data review as per Kasturirangan and Gadgil Report on WGEEP.

The most essential or the staple crop is the rice or paddy. About 600 varieties of rice are grown in the sprawling paddy fields of Kerala. Next to rice is Tapioca and is cultivated mainly in the drier regions. Kerala produces 96% of the country's national output of pepper. The important spices are cardamom, cinnamon, clove, turmeric, nutmeg and vanilla. Other cash crops that constitute the agricultural sector include tea, coffee cashew, pulses, arecanut, ginger and coconut. Kerala also accounts for 91% of natural rubber production of the country. Agricultural production data of 2016-17 and 2017-18 reveal very good and consistent productivity of different crops in the State.

Besides 44 rivers, there are many water bodies (lagoons, lakes, ponds etc.) in the State. Many unique species of aquatic life including crabs, frogs and mudskippers, water birds such as terns, kingfishers, darters and cormorants, and animals such as otters and turtles live in and alongside the backwaters. Palm trees, pandanus shrubs, various leafy plants and bushes grow alongside the backwaters, providing a green hue to the surrounding landscape. 33 species of fishes,106 ornamental and 67 species food fishes were reported. The distribution of these species varies both within a river system and also between river systems and many of these fishes have a highly restricted distribution.

Kerala has number of important archaeological and museums , which are attraction to large number of domestic and foreign tourists. There are no historical / archaeological monuments within the 300 m distance of Silver Line corridor.

Kerala consists of 14 districts spread over an area of 38,861 sq.km. As per 2011 Census, total population was about 33.4 million with 48% male and 52% female population. Out of the total population, Scheduled Caste and Scheduled Tribes are 9.1% and 1.45% respectively. Population density is 860 persons/sq.km with rural and urban population density of 559 and 2097 persons/sq.km respectively. Literacy rate is about 94%. Average family size is 4.25 persons per household. Sex ratio is 1084.

Demographic details of Kerala and all the districts (falling on the Silver Line corridor route and others) are included in terms of total geographical area, population density, total household, total population, child population, SC/ST population, literate/illiterate population, workers pattern, type of workers, employment Pattern (cultivators, agricultural, industrial/ households, others) are detailed. Total workers population is more than one-third (about 34.8%) of the total population of the state.

Major revenue generating activities in the State includes industries 2.57 lakh SSIs/ MSMEs, marine fishing 4.84 lakh tonnes, inland fishing 1.89 lakh tonnes (production in 2017 – 18), agriculture 60% of the total area of the State with about 9.2 lakh persons involved as per 2011 census, and tourism 10.96 lakhs foreigners and 156 lakh Indians visited during 2018 and health care, particularly ayurvedic treatment.

Anticipated impacts due to various activities envisaged during construction and operation of Silver Line rail corridor have been assessed and further mitigation measures have been suggested for different environmental components, viz. air environment, noise environment, water environment, land environment, biological environment and socio-economic environment (Sub Chapter 14.5).

In addition to the mitigation measures suggested to alleviate the minor negative impacts during construction and operation of the project, some of the measures for improvement of environment are proposed to be undertaken, which are Landscaping and beautification, Rainwater harvesting, Bio-toilets in trains, installation of solar panels along the corridor, rooftop of all stations and depots, all station buildings, depot, administrative building and other service buildings are designed based on Green Building provisions. Electrically Operated Feeder Services at all stations, etc.

To protect the environment, over large continuous stretch of the paddy fields under cultivation, viaduct of approx. 14 km of total length is proposed, in lieu of embankment. Further for control of noise and vibration due to running of train, protective measures are suggested for which a provision of Rs 50cr is made available.

Various project alternatives were analysed to avoid and reduce adverse environmental and social impacts as far as practically possible. The comprehensive comparison of all alternatives are presented in sub chapter 14.6.

Analysis of various impacts reveal that proposed construction activity for Silver Line rail corridor shall have impact on all the components of environment, however the magnitude shall depend on the activity carried out on a particular day. With the implementation of suggested mitigation measures during construction and operational phase of the project, these impacts can be minimized to be much within the acceptable limits/levels. Detailed R&R plan has to be prepared to compensate the owners of the affected structures, trees and other agricultural land. Further, environmental management plan. monitoring plan and costs estimation for implementation of the EMP and EMoP during different stages of the project has been suggested (Sub Chapter 14.7 , 14.8 and 14.9 respectively), which will ensure minimum damage to the environment, and the proposed development of Silver Line rail corridor in Kerala will prove to be a boon for the people and economy of the Kerala State.

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